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COMPARISON BETWEEN THE THERMAL MODELS PRESENTED IN THE EUROPEAN STANDARDS ON THE OVERLOADING POSSIBILITIES OF THE LARGE POWER TRANSFORMER UNITS

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Abstract – **The paper compares the operating regimes of the large power transformer units, as they are defined in CEI 60354 and CEI 60076-7, indicating the differences between them. The modification of the operating conditions with the load connected to the secondary winding of the transformer unit is underlined. Further, the paper presents the software applications for evaluating the operation of the transformer in different regimes, their maximum loading limits, as well as the maximum loading time, according to the thermal models presented in the two standards.**

Keywords: *power transformer, thermal modeling, operating regime, loading possibilities.*

1. INTRODUCTION

Transformers are important and expensive elements of the power system. The unusual temperature increases inside the unit may cause the rapid thermal deterioration of the insulation and subsequently the thermal failure of the unit. In order to use the transformer units in the substation at their full capacity and avoid failures due to temperature increase at the same time it is very important to study their entire thermal behavior carefully.

At present special attention is given to the admissible loading regimes of the large power transformer units at the international level. Until recently, it was considered necessary to limit the transformer unit loading, if the system condition allowed it, so that never to surpass their rated power on purpose. This conception is no longer considered efficient as, in case its load is limited at the rated power, the power transformer should be maintained under-loaded most of the time (because the ambient temperature is usually above 20^{o}C). The short-term loading, especially at lower ambient temperatures, does not diminish the transformer life time very much.

In order to know the short-term and long-term loading limits of a transformer unit, the hot-spot temperature should be estimated as precisely as possible. Moreover, the accurate calculation of this temperature helps to realistically estimate reliability and the remaining life time of the transformer unit insulation system.

Consequently, considering the overloading effects on the transformer unit life time, as well as on its efficient operation from the economic point of view, guides to the power transformer loading have been developed.

Some users, who have loaded the power transformers according to the current standards, have noticed that the life time loss calculated in agreement with these standards is less than the life time loss determined by means of a comprehensive analysis of the insulation, carried out after taking out the transformer from the tank. The number of transformers that broke down due to overloading is not so great. These observations determined the users to think that the loading guides from these standards are too restrictive.

2. THE LARGE POWER TRANSFORMER UNITS ADMISSIBLE LOADING UNDER DIFFERENT OPERATING REGIMES

In [6] the following loading regimes are defined:

The normal cyclic loading – is performed at a higher ambient temperature, or at a load current that is greater than the rated one during part of the cycle but, from the point of view of the relative thermal ageing rate (according to the mathematical model), this is equivalent to the rated loading at the normal ambient temperature. This is carried out taking advantage of the lower ambient temperatures or low load currents during the rest of the loading cycle. When the regimes are planned, this principle may be extended to ensure long periods of time when the cycles with relatively higher thermal ageing rate than the nominal rate are compensated by cycles with a lower thermal ageing rate.

Long-time emergency loading – loading resulting from the taking out of operation for a long time of certain elements of the system that will not be reconnected before the transformer attains a new steady-state temperature regime.

Short–time emergency loading – it is an unusually heavy transient loading (for less than 30 min.) due to the occurrence of one or several unexpected events that greatly disturb the normal loading of the system.
In all the transformer unit standards, the rated currents are defined under the following conditions:
- the altitude of the mounting place should not surpass 1000 m above the sea level;
- the average annual temperature should not be higher than +20ºC;
- the air average daily temperature should not be higher than +30ºC;
- the maximum temperature of the cooling agent should not be higher than +40ºC (in the case of the air-cooled transformers) and +25°C (in the case of the water-cooled transformers).

By means of the relations given in [5] and [6], the software applications *HST_LC* and *HST LC TR,* enabling the determination of the operating conditions of the large power transformers that allow a supplementary life time consumption, have been developed.

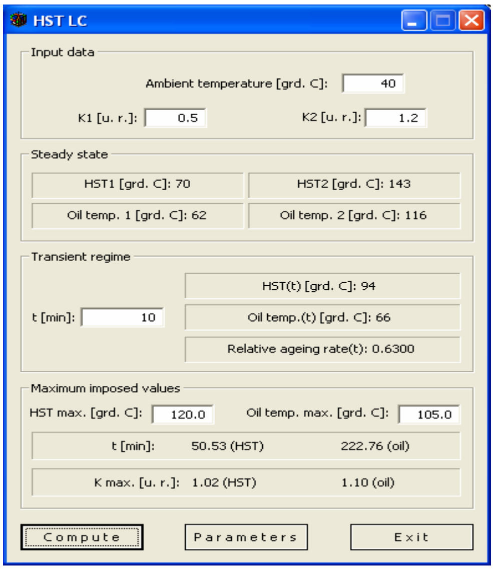

Figure 1: Main window of the software application that establishes the regime of the large power transformer units according to IEC 60354

The main input data are:
- the ambient temperature, in °C;
- the loading time, in minutes;
- the initial loading factor, K_1 and the final loading factor, K_2, in relative units.

The main output data are:
- for the steady-state regime: the hot–spot temperature and the top oil temperature for K_1, and K_2, respectively;
- for the transient regime:

For HST_LC: the hot-spot temperature, top oil temperature and the relative ageing rate considering the loading coefficient K_2 for the time period t, in minutes, specified by the user;

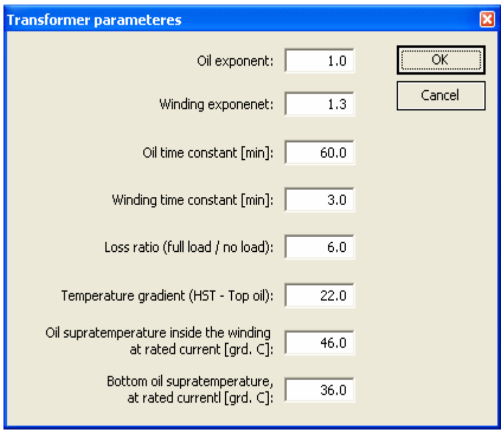

Figure 2: Transformer unit parameter settings window

For HST LC TR: the initial and final top oil temperature, as well as the hot-spot temperature and the ageing rate, in relative units.
- according to the maximum values set by the user for the hot-spot temperature and / or the top oil temperature, the time, in minutes and the maximum value of the loading factor, K_2, in relative units are calculated, enabling the transformer unit safe operation.

The output quantities are calculated by means of the transformer unit parameters defined in [5] and [6] and are displayed in the main window of the user interface, presented in Figure 1 and Figure 3.

The parameters are set by the user in the windows presented in Figure 2 and Figure 4.

The calculated values compared by means of both software applications are given below in Figure 5 to Figure 7.

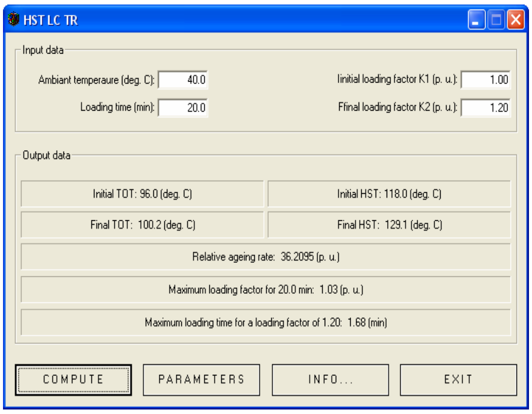

Figure 2: The main window of the software application establishing the large power transformer regime according to IEC 60076-7

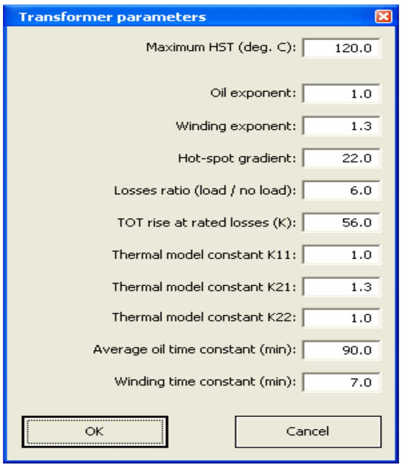

Figure 4: The transformer unit parameter setting window

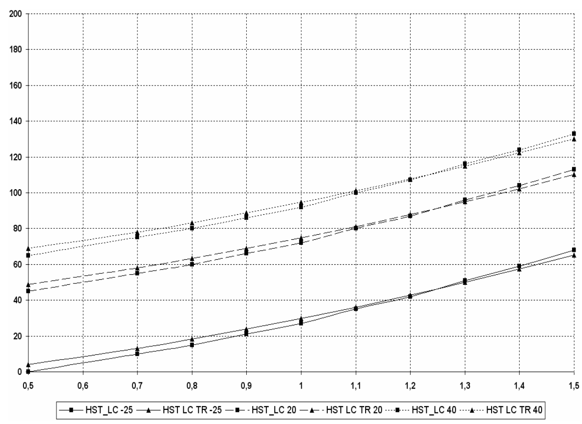

Figure 5: The compared results for different ambient temperatures for $K_1 = 0.5$ and the loading time = 30 min

These figures point out the differences between the two thermal models for different temperatures and loading times.

The thermal model in [6] provides the highest hot-spot temperature when the transformer unit is underloaded, and a lower value when the transformer unit is overloaded, suggesting that the transformer unit can operate longer when it is overloaded according to this loading guide.

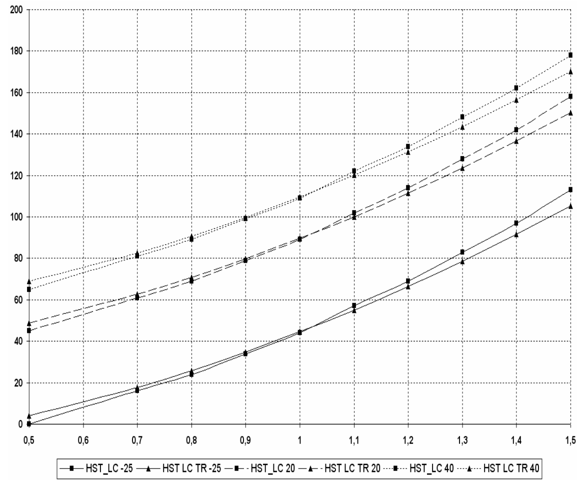

Figure 6: The compared results for different ambient temperatures for K1 = 0.5 and the loading time = 120 min

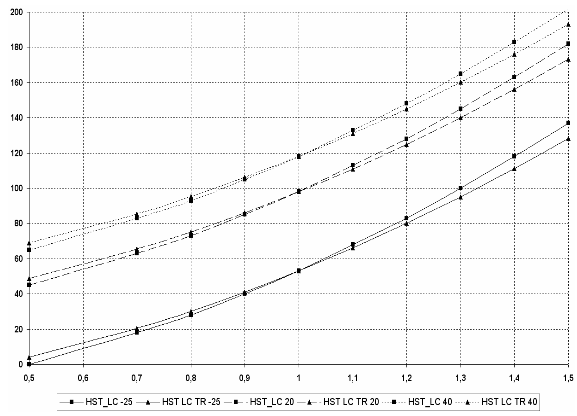

Figure 7: The compared results for different ambient temperatures for $K_1 = 0.5$ and the loading time = 1440 min

At lower loading time values, the differences between the two models are not great (are not significant), but then, when the loading time increases the differences increase in their turn.

Under transient regime, the admissible period of time (in minutes) for operating under overload conditions, determined according to [6] is longer than the one guaranteed by the transformer unit manufacturers.

The calculations have been made by considering an admissible hot-spot temperature of 140 ^{o}C.

3. CONCLUSIONS

This paper compares the operating regimes of large power transformers (whose power is greater than 100 MVA), defined in IEC 60354 and IEC 60076-7.

Software applications enabling the study of the large power transformer unit behavior under different operating regimes, as well as their operating limits have been developed.

On the basis of the data obtained by means of the software applications, the following conclusions can be drawn:
- under steady-state regime conditions, the obtained values are comparable;
- under transient regime conditions the values resulting from the calculation model are much more permissive than the ones guaranteed by the transformer unit manufacturers.

References

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