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An overview of condition monitoring of the power transformers temperatures in the electrical power system

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Abstract. In addition to the analysis of the transformer's assessment in view of the impact on the topology of the transmission, generation and distribution system, the recognition of the status of parameters and performance is a necessity to increase the efficiency of operational work, but the techniques/methods to perform the monitoring are essential. In this context, advanced monitoring techniques as well as smart devices that allow access to continuous analysis and diagnosis of parameters that are considered important for this purpose should be considered. One important condition of monitoring and diagnosis are the temperatures of the power transformers. In this paper are depicted the analysis through trends and alarms of the temperatures by comparing the range of the limits by on-line and off-line techniques. Furthermore, the operational work and the status of monitored parts by year, load and alarms are presented. Prepared monitoring and diagnostic reports, and appropriate corrective measures are taken depending on the status of the power transformer based on their temperatures trend.

Keywords: Power transformers, temperatures, monitoring, electrical power system, measurements.

Introduction

In addition to the analysis of the transformer's assessment in view of the impact on the topology of the transmission, generation and distribution system, the recognition of the status of parameters and performance is a necessity to increase the efficiency of operational work, but the techniques/methods to perform the monitoring are essential. In this context, advanced monitoring techniques as well as smart devices that allow access to continuous analysis and diagnosis of parameters that are considered important for this purpose should be considered. Such results are depicted through trend analysis and alarms by comparing the range of the limits by on-line and off-line techniques. Furthermore, the operational work and the status of monitored parts by year, load, alarms and life expectancy is presented. Prepared monitoring and diagnostic reports, and appropriate corrective measures are taken depending on the status of the power transformer.

Winding and oil temperature measurements

As well known a transformer begins to heat up, the winding insulation begins to deteriorate and the dielectric constant of the mineral oil begins to degrade and so forth. The hot spot temperature is also crucial in assessing the risk of bubble evaluation and in the short term forecasting of overload capability. In fact, the condition of winding temperature is required
under all loading conditions for the operator to take the right decision especially at events, such as rapid dynamics load changes [1]. The following series of equations outlines the algorithm used to compute temperatures in oil-filled transformers [2]. This method can be applied to transformers of any MVA size. The ambient temperature is assumed to be constant and all temperatures shown in °C. The hot spot temperature $H$ is the temperature that determines the thermal capability of the transformer and is given by the following equation:

$$H = \frac{A - TO}{H - TO}$$  \hspace{1cm} (1)

$A$ – ambient temperature, $TO$ – the temperature gradient of the top oil temperature over the ambient temperature, $H$ – temperature gradient of the hot spot over the top oil temperature. The top oil temperature is calculated as follows [3]:

$$TO = AT + OT$$  \hspace{1cm} (2)

Techniques for condition monitoring of power transformers

Power transformers are the most prominent and costly elements in a power grid. In order to avoid any incipient failure, it is important to know the condition and trends of their parameters. Thus, it is desired to monitor the main parameters or all electrical and thermal aspects.

Monitoring techniques including on line and off line methods. On-line monitoring method is one of the most reliable techniques in conducting the parameters and the transformer's work, it can help to prevent incipient failures, to decrease the life cycle cost, to increase availability and reliability aspects.

It is also one of the methods that provide security, reduction of service and maintenance cost. Depending on the installed systems, monitoring includes the main transformer parameters, like; winding temperatures, oil, loads, voltages, moisture, dissolved gas, partial discharges, and other parameters that depend on the various installation devices systems and their cost. Regarding this are included some of the main parameters of the power transformers monitoring system.
Monitoring of the power transformers temperatures-case study

Thus, one of the main parameters for monitoring power transformers operation conditions is the hot spot temperature, which is described through measured and calculated (IEC standards) methods for the peak loads during winter and summer (Figure 2 and 3).

Fig.2. Hot spot temperature, measured and calculated-IEC model at SS Ferizaj 2, AT1 300 [MVA] (winter period)

Fig.3. Hot spot temperature, measured and calculated-IEC model at SS Ferizaj 2, AT1 300 [MVA], (summer period)

To analyze the main thermal parameters of power transformers are used measurements during the different time periods of power transformer operation through the monitoring system (Transformer Monitoring System-Koncar). Measurements are performed during the on-line transformer’s work in different time periods and loads.

In this case, the thermal parameters like; oil and winding temperature, calculated temperature such as hot spot temperature of the autotransformer is presented. Thus, comparisons are depicted between the model according to the IEC standards, taking into account the above expressions and measurements through the monitoring system installed at SS Ferizaj 2 400/110 [kV].

This suggests that comparative methods should be used in such cases so that mistakes and monitoring are as accurate conclusions and the control of integrated measuring devices and instruments in the monitoring system, such as Pt – 100 probes, sensors and other devices. It also helps in the correctness of the actions of responsible staff and operators in taking appropriate measures regarding the unexpected anomalies.
Figure 4 shows the trend of thermal parameters, such as hot spot temperature, top oil temperature, load factor and ambient temperature during the summer period (01.08.2015 to 07.08.2012). The trend of thermal parameters shows that despite the high temperatures up to 40 °C and small load factor, the hot spot temperature reaches up to 60 °C, while the top oil temperature is about 48 °C. Thus, the autotransformer operates under normal operating conditions regarding the oil temperature (Figure 4).

![Graph showing temperature measurements and load factor of power transformer at AT1 in S8 Ferizaj 2 (summer period)](image)

Fig. 4. Temperature measurements and the load factor of power transformer at AT1 in S8 Ferizaj 2 (summer period)

Figure 5 shows the trend of the thermal parameters during the winter period (20.01.2016 to 27.01.2016). As a result, for the stretch temperature about (−20 °C) it is noticed that the autotransformer thermal capacity is within operating limits, and so it is under normal operating conditions. Thus, the hot spot temperature goes down to 40 °C and the top oil temperature at the top of the main tank is around 36 °C. Therefore, trend analysis of the temperature measurements is at the acceptable level of operating conditions and do not endanger the work of the autotransformer in the thermal aspect.

Furthermore, in the diagram as shown in Figure 5 regarding temperatures; hot spot, top oil temperature, ambient temperature and load factor, is concluded that the oil diagnostics, hotspots in the active parts of the transformer, as well as load factor, indicate in the performance regarding the transformer insulation system. It is important to emphasize the thermal aspect, regarding the ratio of the parameters, then comparisons are necessary for the searching of anomalies between each other.

Temperatures are a specific overview in addition to the finding incipient faults in the insulation system, not forgetting the load condition, even though oil degradation is a factor that gives the alarm in enhancing the respective temperatures. However, currents and temperatures will result in an increase in the losses and power transformer’s risk level. Sometimes the hot spot temperature (HST) represents an overloading or severe problem inside the power transformer and shows the performance of the lifespan when they are higher than the normal range. However, sometimes most of the faults and abnormal operating conditions of transformers can be detected based on the trend and measurements of the hot spot temperature. As well known, the hot spot temperature besides others is related to the top oil and ambient temperature.
Fig. 5. Temperature measurements and the load factor of power transformer at AT1 in SS Ferizaj 2 (winter period)

Discussion of the cases related to the status of the power transformers parameters such as moisture in oil is helpful in achieving results for defining the transformer status during their work. It is also important to perform other analysis. Through the methodology like; fuzzy logic model, condition assessment or diagnosis of the power transformers can be carried out automatically. Measurements values of moisture in oil and moisture level are based on the many models like; fuzzy logic model, and the transformer condition status is automatically obtained [4].

Conclusions

The model of oil and winding temperature analysis includes parameters, such as top oil temperature, load factor and ambient temperature, based on trends and alarms at different time periods can be examined and defined the hotspots in the overall transformer parts. In this case, based on analysis that relies on trends the autotransformer is under good operating conditions. By the trend of the parameters that are presented in the Figure 4 and Figure 5, is identified that the relation between each other considering the time periods and loads of the power system, respectively, as a result, power transformers should be analyzed according to short circuits and partial discharges. According to the trend, as shown in Figures 4 and Figure 5, the change of the values of the analyzed parameters, based on such diagrams are higher during the summer than winter period, although the load factor is higher during the winter period. It implies that ambient temperature plays a significant role that needs to be highlighted and to do further analysis. Therefore, the analysis of temperature measurements in different cases is very significant when compared to the values calculated by standards, so that they help in the effective operation and prevent unforeseen power transformer failures.

References

