EFFECT OF ASYMMETRY ON RELIABILITY OF TRANSFORMER 630 KVA

M. KUČERA, M. GUTTEN, S. KUČERA, M. ŠEBÖK
Faculty of Electrical Engineering, University of Žilina,
Univerzitná 1, 01026 Žilina, Slovakia, Email: gutten@fel.uniza.sk

Abstract: *This article describes analysis of frequent faults on 630kVA, 22/04kV transformer which is connected in star - delta configuration (Dyn1). Multiple breakdowns in a short (eight months) period made us to analyse its operation with a view to completely resolve or at least diminish this issue which subsequently cause considerable financial loss.*

Key words: transformer, analysis, asymmetry, measurement

1. Introduction

Reliability of a technical device cannot be set with an absolute certainty. Reliability can be considered as a quality time fragment which is affected by technological discipline and a level of personnel qualification.

In all applications we can see that decreasing level of reliability comes with:

- higher levels of sophistication of an equipment,
- harsh work environment.

Reliability of distribution transformers is highly dependant on their type of use. One of the significant factors affecting its operational life is temperature, which can be influenced by:

- degradation of insulation systems,
- effects of short currents,
- symmetric overload over nominal value of a transformer,
- asymmetric overload at the transformer output.

2. Theoretical Analysis of Distribution Transformer Failures

The area of analysis and synthesis of a closed electroenergetic system supplied from a distribution transformer is from the reliability point of view, whilst providing a non-stop operation, one of the most crucial tasks.

In current practise of prophylactics of power transformers dominate methods evaluating dielectric-electric parameters focused on insulation system or on transformer coiling.

From point of view of mechanical state in active transformer 630 kVA (fig. 1) parts that were measured, we had very little information about strength of this power transformer. (In some cases, as mentioned in [1], deformation of a transformer coiling and its age had as a result decommissioning of a unit).

Fig. 1. Measured transformer 630 kVA, 22/0,4 kV, 16,5/909 A after disconnection from operation

From a theoretical analysis a probability of faultless operation can be defined by means of fault intensity as follows:

$$R(t) = e^{-\int_0^t \lambda(t)dt}, \qquad (1)$$

where λ is fault intensity,
t is time in operation.

In a period of random faults of a system, if assumed that λ is constant, formula (1) can be simplified to:

$$R(t) = e^{\lambda t} \qquad (2)$$

Presumption stemming from formulas (1) and (2), has a rational basis. Value λ is affected by physical, mechanical, chemical and technological factors, under which influence λ can exponentially change. To solve this problem it is particularly suitable to apply analysis of current passing through windings which cause losses. These losses significantly affect operation of a transformer. The losses are mainly transformed to heat. Overheating minimises use of active materials and hence the overall output as well. Short time overheating is for insulation much less detrimental than prolonged overheating. However it is not the average temperature of winding, oil etc, but a temperature of transformer hottest point that we should bear in mind.

In present days, the second but equally important identification is EMC, which historically used to be used mainly to protect equipment from radio signals, but now involves a broad spectrum of electronic and electrical engineering principles. Investigating EMC one always the basic EMC flowchart, depicted in fig.2.

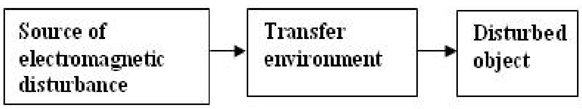

Fig. 2. Basic EMC flowchart

3. Analysis of Transformer Consumption

Consumer is connected to 22kV public distribution network through distribution transformer 22/0,4 kV, 16,5/909 A with nominal output of 630 kVA. Supply of electrical energy is measured at the secondary side of a transformer via current measuring transformers 1500/5A incorporated within bus system 400V – in own distribution plant. Connection of distribution plant from mast transformer station is realised with AYKY cable.

Analysis of electrical energy consumption with focus on minimising reordered ¼ hour maximum was carried out by The Slovak Republic Energy Inspectorate. The method and its principles of this measurement are documented. From the energetic point of interest are important mainly ¼ hour maxim and their values in the investigated period. What amount and in what particular times was consumed to maintain continuous and smooth operation is depicted in graphs in fig.3.

After the analysis carried out by The Slovak Republic Energy Inspectorate in the establishment we did this work, installed output was not increased. The survey recommended the consumer to install means of ¼ maxim regulation, utilizing electronic regulator EKS.

After instalment of EKS regulator, thermal overload occurred again and so did faults on transformer 630 kVA.

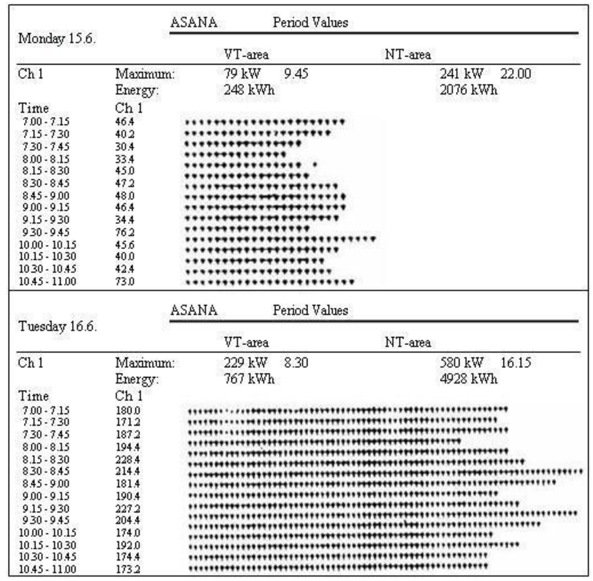

Fig. 3. Consumed Electrical Power 2 Days (1/4 hour maxim)

4. Power analysis at the Transformer Output

A well known phenomenon of asymmetry was analyzed by measuring current and voltage on phases L_1, L_2 and L_3. Currents on the secondary side of the transformer were measured via measuring transformers 1500/5A, phase voltages were recorded directly from bus bars.

Flowchart and schematics of electro-energetic feed of our technology equipment, its recording, and measuring equipment used are depicted in fig.4.

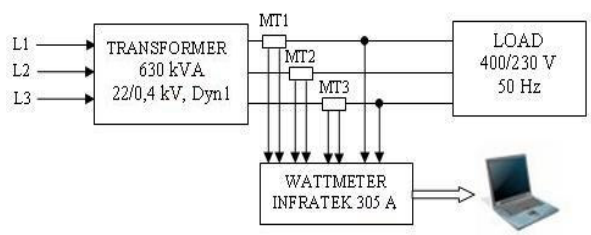

Fig. 4. Flowchart and Schematics of Electro-energetic Feed of technology Equipment and its Measurement

At the experimental analysis especially stresses point of interest was on measuring currents in phases. Up to date measuring equipment allowed us to carry out our measurements without interrupting technology operation. Recording was in 1 minute intervals over a period of 1 week. A graph representing results of this measurement is in fig.5.

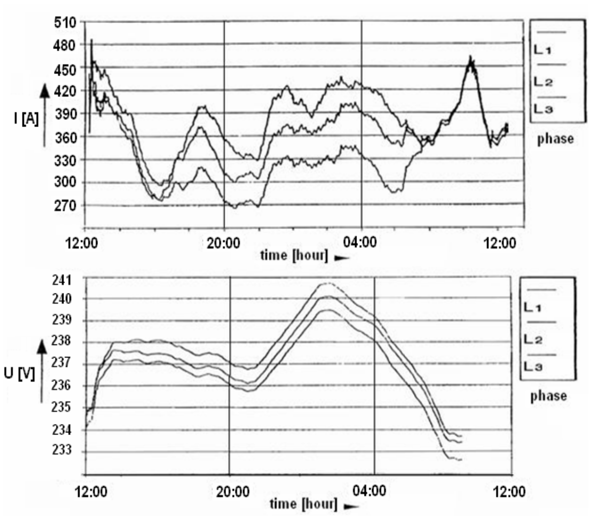

Fig. 5. Output Currents and Voltages at the Output Side of a Distribution Transformer

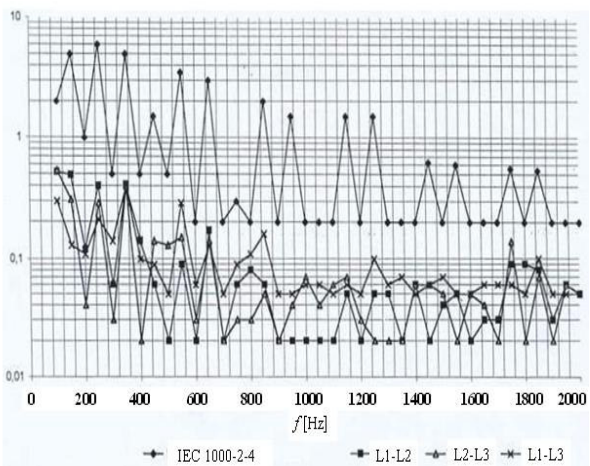

Fig. 6. Harmonic Analysis

5. Harmonic Analysis at the Output Side of a Transformer

Application of fully regulated electric drives requires watching parameters of energy network also from the point of harmonic analysis. The problem of clear function of electric energy is important chiefly because of:

- effect of a non-sinus function on an inherent equipment,
- effect of a non-sinus function on other electrotechnical equipment.

In higher bands impacts for power application are minimal and for this reason we concentrated on the analysis of energy spectrum only. Graphical presentation of this analysis for f = 0÷2000 Hz is in fig.6. It is obvious to see interphase asymmetry, which comes from comparison of phases and their limit values.

3. Conclusions

In this paper we showed 2 different analysis carried out on the same distribution transformer 630 kVA 22/0,4 kV, Dyn1 with the same characteristics of consumed power. One analysis is from the point of optimisation of ¼ hour maxim and the second investigates the symmetry of load on L_1, L_2 and L_3.

While at the optimisation of ¼ hour maxim we measured the mean value and the results suggested a fault (with automatic regulation), analysis of load symmetry showed deviations up to 35% between phases L_1, L_2 and L_3. Such asymmetric load for a transformer connected in Dyn1 is quite large. (For similar asymmetric loads over 20% it is more advisable to use connection Yzn1).

Asymmetric load on phases is accompanied by greater losses. By higher power usage of a transformer, the overloaded phase causes overheating of coiling, faster ageing of insulation and hence higher fault frequency. Anomalies we found were caused by unbalanced 1-phase load.

In order to achieve results of electroenergetical state as accurate as possible, in our measuring period of 1 week (which means 20 technological cycles) both voltage and current were measured on primary and secondary side too.

From the results found in our analysis we can say that if the same technology operation is maintained and the energy distribution balanced is tuned more finely – this distribution transformer is able to provide reliable operation and fulfil EMC criteria at the same time.

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