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THE VALUE OF INFORMATION OBTAINED THROUGH TRANSFORMER MONITORING SYSTEM

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Abstract – Transformer reliability and availability are keys to a profitable process of power generation and transmission. On-line supervision of transformers improves their reliability, positively influencing correct and safe functioning of the whole power system. To achieve the desired transformer availability, the user should have information about the transformer state and operating conditions. Especially, he should have information about incipient faults before they escalate into failures. A transformer monitoring system with ability to supervise all the significant transformer parameters is the proper way to obtain valuable information, and on the basis of trustworthy information to achieve the desired reliability and availability, personnel and environment safety.

Diagnostics combined with monitoring information results in better diagnostic decisions and recommendations.

Information obtained through monitoring system enables also transformer producers to improve and optimize the design and the production process on the basis of real-time operating parameters, what results in better features of transformers.

The insurance companies scale insurance premium for equipment insurance according to the state of equipment, frequency of failures and other information based on risk evaluation. The monitoring system information could provide data for evaluation of the transformer state and prediction of possible failures, what is important for insurance.

Keywords: information, monitoring, power transformer

1. INTRODUCTION

The transformer monitoring system is known as the system that detects incipient faults, and helps the transformer user/operator to manage transformer operation. In this way it prevents failures, or reduces fault consequences. It also helps to maintain the transformer on the basis of the actual transformer state. If the fault develops so quickly that it is not possible to react and prevent the failure, then monitoring system will provide detailed analysis of fault causes.

The monitoring system is based on a PC or a powerful controller (for example PAC – Programmable Automation Controller). The system incorporates many algorithms and models that simulate transformer operation. Also, the system manages many important transformer data and parameters. Because of its mentioned features, the monitoring system is very convenient for upgrades that can "add value" to a specified information, or present existing information to different users in a specified way. The point is that the necessary upgrade means the development of proper software modules, demanding no additional sensor, and no other system component. It means that it is possible to get added information value without material costs.

2. SYSTEM ARCHITECTURE

The transformer monitoring system consists of a subsystem installed on the transformer, and a computer (server) with monitoring application located in the control room. The server in the control room and the subsystem on the transformer communicate through TCP/IP fiber-optic communication link (Ethernet) Fig. 1 [1].

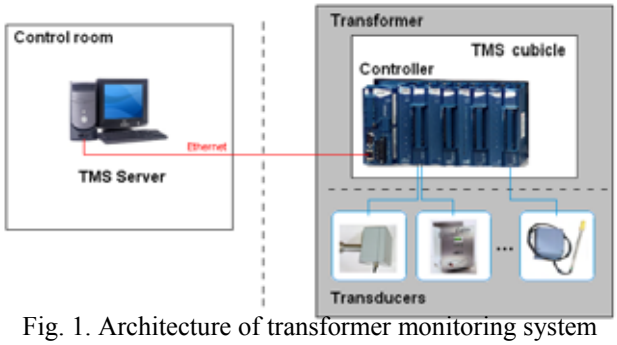

Fig. 1. Architecture of transformer monitoring system

The subsystem on the transformer consists of transducers for measurement of different quantities and a controller for performing the monitoring. Transducers are installed on appropriate transformer points, and the controller is installed in monitoring cubicle with other devices (over-current protection, uninterruptible power supply etc).

Windows XP operating system, program for monitoring, and the database are installed on the server.

The monitoring system exchanges data with other systems (control, protection etc.) in the substation over the server, or over the controller.

On the basis of measured quantities and transformer data, the system estimates various parameters important for transformer reliability using integrated tools and models.

3. INFORMATION CREATION

Different kinds of information are created in the monitoring system, and their creation is performed in different ways.

One kind of information results from measurements of different quantities. These are measurement-based information.

The second kind of information results from algorithms for parameter estimation. Algorithms are used for calculation of parameters that could not be measured, or their measurement would be costly. These are estimation-based information.

The system gives a third kind of information on the basis of comparison of actual (measured or estimated) values and predefined limits of values. If the actual value is higher or lower than the predefined limit, the system generates alarm-based information.

The fourth kind of information results from models that simulate transformer operation and estimate values of parameters [2]. This is model-based information.

And, finally, the fifth kind of information is generated on the basis of comparison of the actual (measured) value of a quantity and the model result. If the difference of compared values is higher or lower than allowed, the system generates model-alarm-based information.

The in-dept creation of the first kind of information, and their flow through the monitoring system are described here.

Information on the value of a measured quantity arises in a sensor of the appropriate transducer. This information (signal) is converted in transducer's analog-to-digital converter (ADC) into a digital signal, and in digital-to-analog converter (DAC) into a 4-20 mA or similar analogue signal. The information is transferred into input controller module over copper cable through different protective devices (over-voltage and/or over-current protection devices – OV&OC protection).

Controller input module performs signal sampling and time stamping. Reading and timestamp are parts of created measurement-based information.

Real-time application for monitoring (TMS FP) installed on the controller checks the information, and, if necessary, passes it in its own algorithms and models, in the local database located on controller (LDB) or in the application for monitoring on server (TMS), in Tag Engine, or in the database located on server.

In the mentioned algorithms and models, estimation-based information are created.

Any of these information can be passed to the server, or through controller's output modules to other systems in the transformer station or power plant.

Information passed to the server flows through copper/fiber-optic Ethernet link, to the TMS application or to the database.

In TMS application information is used for (visual or acoustic) presentation to the user, or it is used in algorithms and models for creation of additional information.

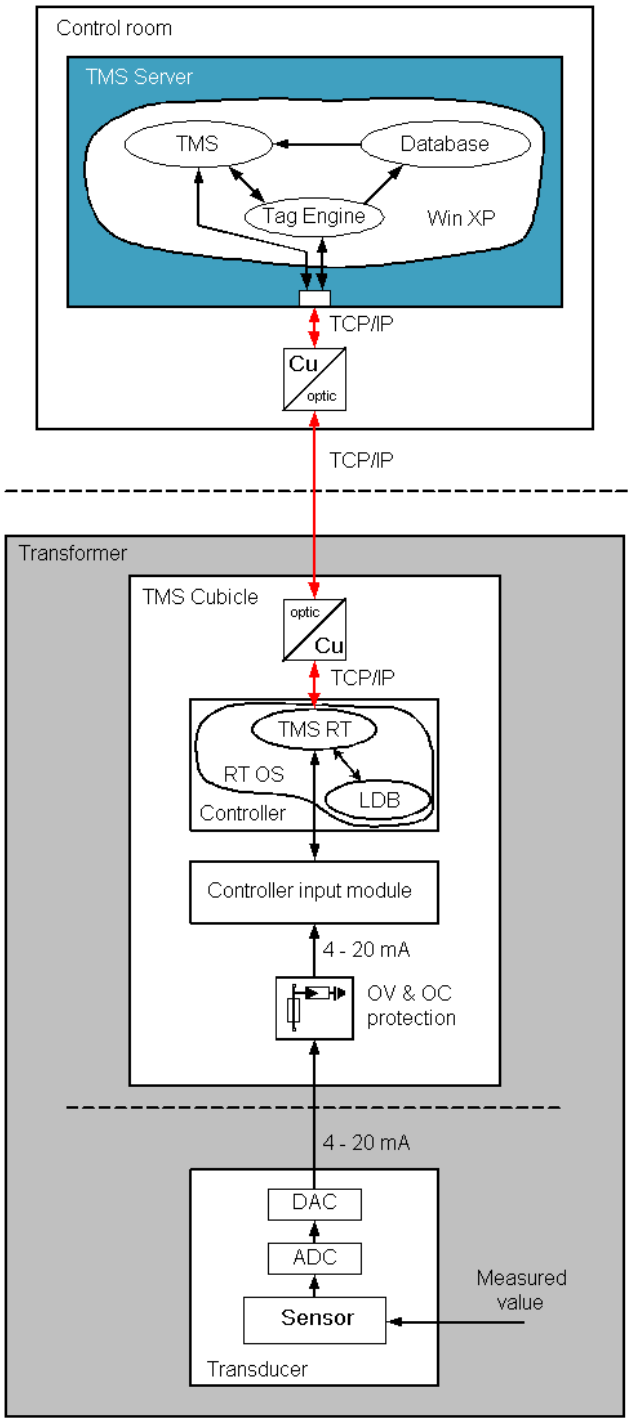

Fig. 2. Example of information generation and its flow in the monitoring system

Also, at request of the user of TMS application, TMS can create additional information on the basis of actual

and/or historical information. The user of the application can be a transformer user or operator, a diagnostician, a transformer owner, an insurance expert, a researcher, a student etc.

4. USER INFORMATION

The monitoring system provides insight in the transformer state and operating condition in every moment by giving different kinds of information.

There are also additional kinds of information, but these above mentioned are the most important for the user.

All specified information are at the user's hand. He can monitor them and make decisions more reliably. But if he does not want to monitor the transformer state continuously, the system takes care of the transformer and warns the user in case of failure possibility. The system is able to monitor one or more transformers; it recognizes incipient faults in the transformer and warns the user in the desired way – independently of the kind of the transformer and/or its parameters.

Fig. 3. Different kinds of information are presented to the user

5. DIAGNOSTICIAN INFORMATION

Diagnostic tests applied to power transformers are: winding resistance measurement, insulation resistance measurement, leakage reactance measurement, recovery voltage measurement, no-load current measurement, frequency response analysis (FRA) etc. At the same time transformer's high voltage bushings are tested, applying capacitance and tan delta measurement.

At winding resistance measurement, the mean winding temperature is very important. Diagnosticians measure temperatures at many places on the transformer and estimate this particular temperature. The monitoring system with ability of winding temperature estimation (Fig. 4) that operates during this test provides a more accurate winding temperature value resulting in decreasing measurement uncertainty and facilitating the test Fig. 5.

In insulation resistance measurement for diagnostic purposes, the winding temperature is also very important data. At this measurement the monitoring system tool can be used for more accurate winding temperature estimation.

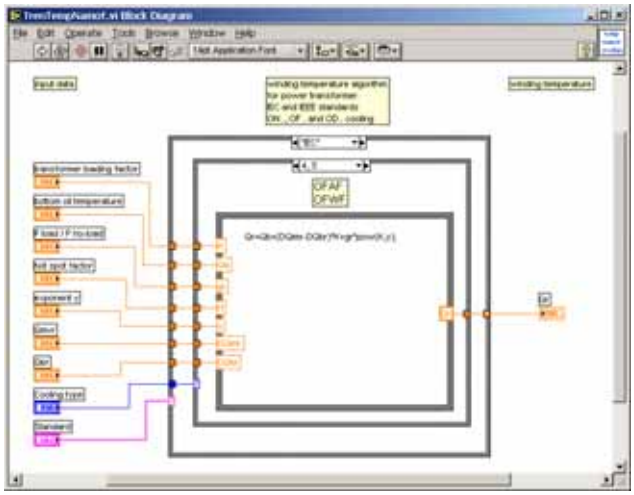

Fig. 4. Software tool for mean winding temperature estimation

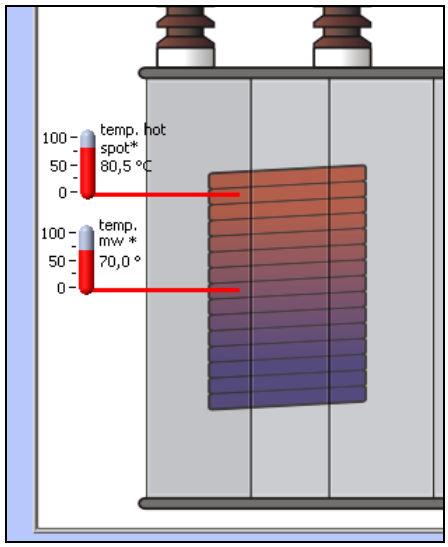

Fig. 5. Mean winding temperature information from the monitoring system

During the leakage reactance test for diagnostic purposes, if measurement results differ from the referent measurement, the current archive data and alarms from the monitoring database can be helpful. It could provide insight in short-circuit currents and inrush currents that transformer was exposed to. On the basis of this information, diagnostician can make a more reliable conclusion. Mentioned archive data can also help to judge the responsibility in the case of transformer failure in guarantee period or in other situations.

If the measurement result of tan delta of bushing differs from the referent measurement result, traditionally diagnosticians will compare actual measurement result with result of last measurement. He will give recommendations on the basis of this comparison in accordance with accepted criterions. If a transformer is

equipped with a monitoring system that has the tan delta monitoring ability, diagnostic conclusions and recommendations could be different if tan delta trend increases slowly, or if it increases rapidly.

6. TRANSFORMER PRODUCER INFORMATION

Transformer producers have design departments with very competent designers and powerful design tools. After all, producers that produce special transformer units sometimes have difficulties in design of these units or their parts. For example, if a designer can choose between two or more solutions for one transformer part (winding leads, cooling channels etc), and if it is not absolutely clear which solution is better, traditionally he will chose the one he considers to be the best. But if it is possible to find a similar unit already operating with the monitoring system, the designer will be able to check temperatures, losses and other transformer parameters significant for choosing the solution Fig. 6, and possibly select some other solution, not the one used before. After using different solutions, producer will be able to monitor similar transformers with different solutions, and on the basis of "real-life" information quickly conclude witch solution is better. The result will be a transformer with better features, and it will bring benefits both to the producer and to the user.

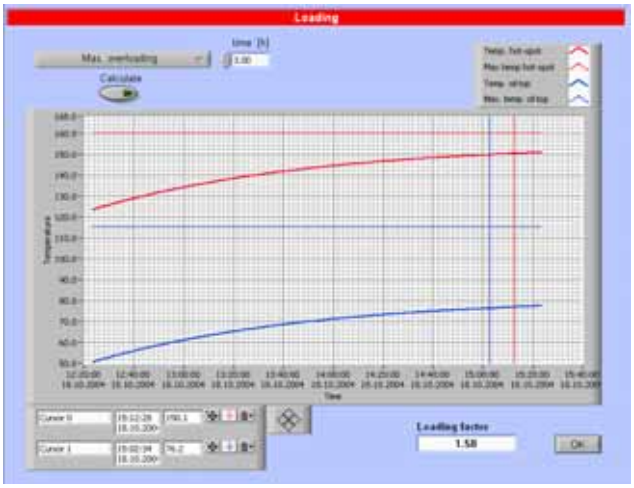

Fig. 6. Loading check on the basis of real-time parameters during transformer operation

A similar situation is when a producer buys transformer equipment, e.g. bushings, from many suppliers. After input testing of the equipment before installation on transformer, after testing the complete transformer, with monitoring of bushing capacitance and tan delta, the producer has the possibility to get information on bushings and transformer state in operation. On the basis of data from many transformers, the producer can statistically determine the best producer of bushings, and even more, he can determine the best type of bushings.

Similarly, the producer of a transformer can monitor many other transformer parts and used materials, and in this way the transformer monitoring system can get attributes of control quality system too.

7. INSURANCE COMPANY INFORMATION

Most owners of power equipment insure their properties. The same is with power transformers. Many insurance companies give a bonus to insurance premium for proper maintained equipment. We also expect the same treatment for power transformers equipped with a proper monitoring system that can provide insight into the transformer state to an insurance expert Fig. 7, especially when they can recognize incipient faults and prevent a failure, or mitigate consequences. It means that insurance payments for monitored equipment should be less then for unmonitored equipment.

Fig. 7. Check of historical alarms of transformer parameters

8. CONCLUSION

Power transformer monitoring system provides different kinds of information. All of them are at the user's hand. On the basis of these information the user can: detect incipient faults, and prevent or reduce fault consequences, have continuous information on transformer state and operating conditions, use maintenance based on actual transformer state, increase availability, optimize transformer management, analyse fault causes, improve protection and safety of personnel and environment etc.

The transformer user can share these information with diagnosticians, transformer producers and insurance companies, and in this way increase the value of collected information making additional benefits from all of them: getting better diagnostics of transformer health state, getting more reliable recommendations, paying less insurance premium and winning better transformers in the future.

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