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Autotransformer monitoring system

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Abstract. This paper describes the monitoring system of autotransformer installed in the Poręba and Bieruń substation. Apart from the monitoring system carried out on microprocessor controllers ADAM 5000, a process of adapting the transformer for the system of data acquisition was also described.

Key words

Monitoring, HV autotransformer, microprocessor, controller, ADAM5000.

1. Introduction

High voltage autotransformers are one of the most important and expensive devices in the power system. Hence, it is important to remotely control and monitor their condition. To meet current requirements of power companies it is essential to constantly improve functionality of autotransformer monitoring systems. The main aim in using such systems is to ensure continuity and reliability of the operation of autotransformers, reducing costs and economic losses associated with possible failures.

This article concerns the system which collects data from autotransformers. The system was realized in the **Institute of Electric Power Engineering at Warsaw University of Technology** and was installed in the Poręba and Bieruń substation.

2. Adaptation of autotransformer

For a proper operation of the monitoring system, it was necessary to adapt the equipment installed on the transformer to the needs of data acquisition. After modernization, the transformer consists of following devices:

- radiators control scheme – it's main task is to control pump and fans motors. This scheme includes:
  P1 to P4 - oil pumps,
  W1 to W12 - fans,
- sensors for measurement of temperature:
  T01 to T08 sensors for measurement of oil temperature PT100,
  T09 sensor for measurement of ambient temperature PT100,
  T010 sensor for measurement of top oil temperature,
  TR1, TR2 sensor for measurement of core temperature,
  TS1 sensor for measurement of temperature in

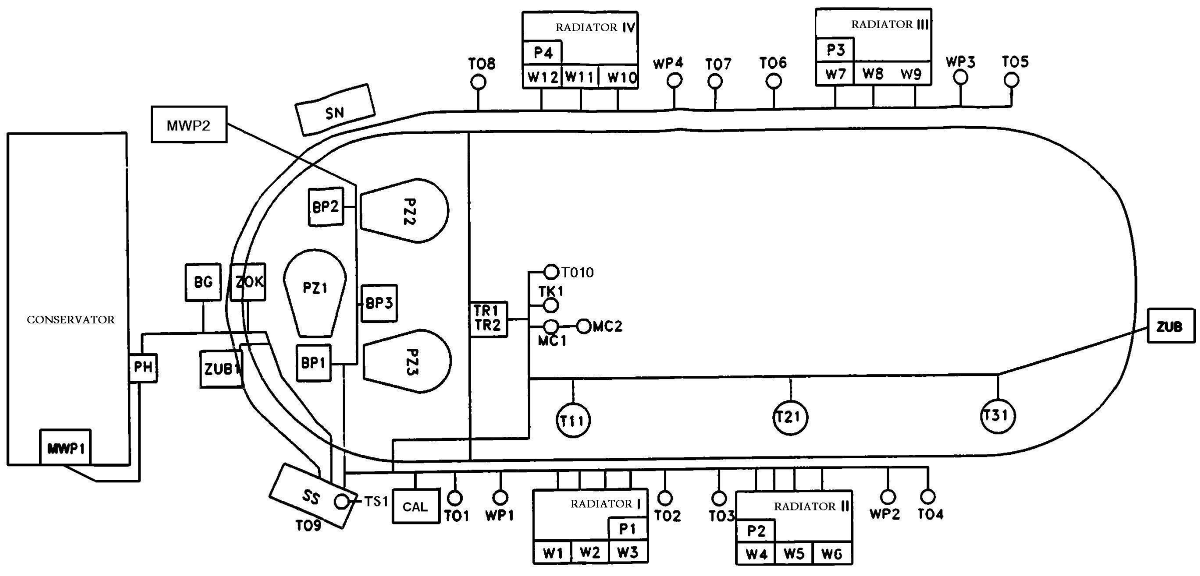

Fig. 1. Target spatial arrangement of sensors and indicators, and the wiring of the transformer AT1

cooling cabinet,
- oil contact thermometer, type OTI, AKM, Qualitrol, tag: TK1,
- thermal model for determining the temperature of windings, type 509-300, Qualitrol, tag: MC1,
- monitoring devices of dissolved hydrogen and water in oil, CALISTO, Morgan Schaffer, tag: CAL,
- CTs of 220kV site (secondary currents: 5A) tag: T11, T21, T31,
- sensors detecting oil flow, type WP-125, tag: WP1 to WP4,
- transformer tank and conservator oil level gauges tag: MWP1, magnetic oil level gauge of transformer tank type: MWP-345, IEN Łódź, and MWP2 – magnetic oil level gauge of conservator type MMK 630, Messko,
- conservator shutter valve, type ZOK-80, IEN Łódź, tag: ZOK,
- operation gauges of pressure relief device, tag: ZUB, ZUB1
- Buchholz relay of main tank and tap changers, tag:
  BG – Buchholz relay – BF80/10,
  BP1, BP2, BP3 – Buchholz relays – URF25/10.

The location of each of mentioned devices is shown in Figure 1.

3. Monitoring system

Autotransformer monitoring system is based on a microprocessor controller ADAM5000 TCP.
The controller is equipped with three analog cards, each one with 8 inputs, and five cards, each one with 16 digital inputs.
This allows to monitor up to 24 analog signals and up to 80 digital signals using the microprocessor controller.
Analog signals come mainly from the PT100 temperature and humidity sensors. Digital signals are generated by various types of protection relays and devices located on autotransformer. The following sections will partly describe measuring and monitoring schemes.

4. Cooling system

After realization of the autotransformer monitoring system, the controlling of cooling system needed to be modernized. Microprocessor controller WAGO was added during necessary changes. This controller performs switching of leading group according to the program and indicates active radiators group. Block diagram of the radiators control scheme is shown in Figure 2.
Digital controller Qualitrol 509-300 was used as a thermal model to control the cooling system. In order to determine the top oil and windings temperature, system uses: PT100 sensor for measurement of top oil temperature, PT100 sensor for measurement of ambient temperature and intermediary current transformers for measurement of one current in upper winding. Exceeding the oil temperature of 45˚C, 55˚C and 65˚C results in closing following digital outputs contacts. These changes are transmitted to the WAGO controller and monitoring system. In addition, the microprocessor controller, indicates when the windings temperature exceeds 115˚ C and 130˚ C. This operation is possible due to calculations, which take into account ambient temperature.
WAGO microprocessor controller performs switching of leading radiator once a month or once a week – according to the version of installed software.
When oil temperature exceeds 45˚ C, logic will cause next radiator to operate every month (or every week). By ensuring the same time of operations of every radiator, excessive use of one of them is prevented. Digital outputs control intermediate relays which switch radiators to operate.

The monitoring system uses digital inputs to collect following data from the system which controls operation of radiators:
- excess of the subsequent steps of the oil temperature of 45, 55 and 65˚C (information from Qualitrol 509-300 controller),

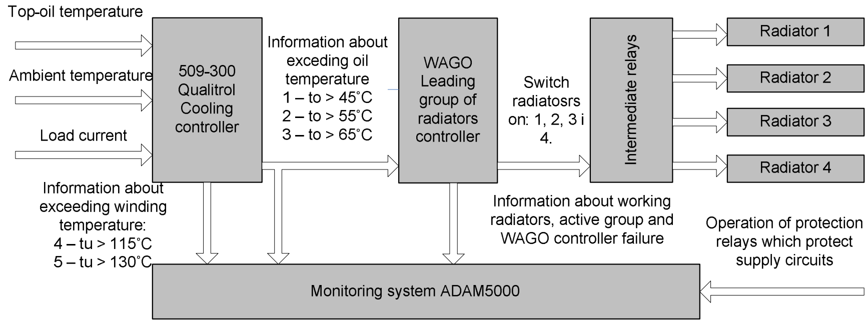

Fig. 2.The block diagram of radiators control scheme

- excess of the subsequent steps of the winding temperature of 115˚C and 130˚C (information from thermal model of Qualitrol 509-300 controller),
- start each of the four radiators to operate, (information from the WAGO controller),
- current number of radiator which is set as a leading radiator (information from the WAGO controller),
- WAGO controller failure,
- oil flow through each radiator, (information from the sensors detecting oil flow),
- operation of protection relays which protect circuits supplying fans and oil pumps.

5. Measuring schemes of temperature and humidity

Signals from various sensors are transmitted to analog inputs in ADAM5000 recorders. Those sensors are
- temperature sensor PT100, placed at the inlet and outlet of each of the four radiators,
- temperature sensor PT100, located in upper layer of oil, in core and the outside – in order to measure ambient temperature,
- sensors for measurement of temperature and humidity in radiator control cabinet and tap changer.

6. Recorder scheme of tap changer operation

Particular attention should be paid to the recorder scheme of tap changer operation. The main element here is a programmable controller ADAM5510, which collects analog and binary signals. Digital inputs are connected with real and reactive power transducer – Tillquist PQ 400. Demand for real and reactive power can be determined, based on actual values from CT's and VT's installed in circuits supplying tap changer's motor. Such information shall be scaled in standard 4…20 mA, which may be recorded in the ADAM5510 controller.

After receiving tap changer operation signal, the controller starts to record, storing power values with 5ms resolution in cache. At the same time controller records the current position of tap changer. After finishing the cycle of changing position of tap changer, controller sends a packet of data with collected information to the server for later analysis. This enables the determination of the position on which tap changer was working most often, and what the current load was. This way, it is possible to determine which contacts are most used.

Qualitrol 509-300 which controls radiators, is also equipped with module responsible for monitoring of tap changer. Controller collects data from one CT installed on power circuit of tap changer, from one CT installed in bushing insulators and get information about the current position of tap changer. Thanks to that the cumulative current which flows through tap changers can be measured. In addition the motor load of tap changer can be estimated.

In addition to a separate ADAM5510 recorder, tap changer operation is also monitored by ADAM5000 controller.

Following information is sent to the controller:

- tap changer operation in minimal and maximal direction,
- tap changer reach lower extreme position and upper extreme position,
- actual position of tap changer,
- type of control: local or remote.

Controller receives information about operations of protection relays located in tap changer cabinet, such as:

- asymmetry of tap changer motor supply,
- short circuit in tap changer motor,
- short circuit in supply of motor control
- opening motor control cabinet.

7. Measurement of water and dissolved hydrogen in oil

Scheme for measurement of water and dissolved hydrogen in oil uses Calisto device. Data concerning measured quantities are transmitted to concentrators of monitoring system using RS485 standard and MODBUS RTU protocol. In the same way, data concerning following states of binary signals are transmitted to concentrators:

- excess of 1 level of hydrogen content,
- excess of 2 level of hydrogen content,
- excess of 1 level of water content.

Several concentrators of monitoring system continuously request data from Calisto unit using RS485 standard, so that Calisto failure is signalized. If there is no response within a few seconds, then the device is inoperable.

8. Signals from power transformer protection

Some of the power transformer protection and measuring schemes, are monitored by ADAM5000 controllers. The system collects following information:

- operation of shutter valve,
- operation of Buchholz relay,
- excess of the first minimal and maximal level of oil in the main conservator,
- excess of the minimal and maximal level of oil in the tap changer conservator.

9. The measurement of currents and voltages

Optionally monitoring system can be equipped with N14 metering devices, which are produced by Lumel company. In addition to standard measurements of currents and voltages on both sides of the autotransformer, they allow to get such electric quantities as: real, reactive and apparent power, energy and frequency. ADAM5000 gets information in RS485 standard using MODBUS RTU protocol.

10. Communication between microprocessor controllers

Data acquisition system was doubled in order to increase the reliability of operation of the monitoring system. ADAM5000 concentrators play role of monitoring units. Both concentrators have Ethernet LAN

Fig. 3. The view of assembler monitoring system in Poręba substation

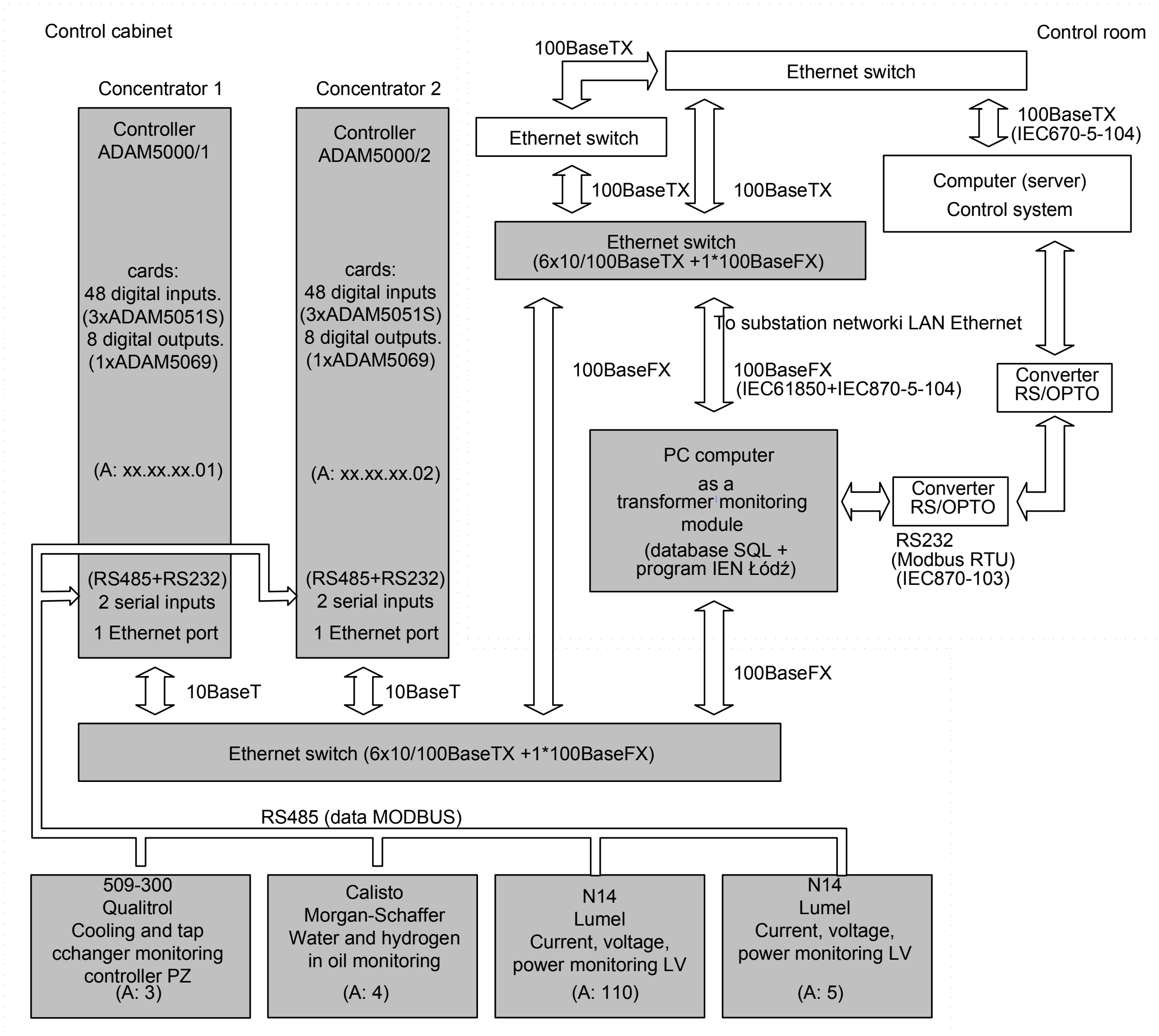

Fig. 4. Communication scheme between 509-300 controller, ADAM5000/1 controller, ADAM5000/2 controller and data transmission to PC computer

connection and besides of that, they work in RS485 ring. The concentrators communicate with such devices like:

- Calisto, for measurement of dissolved hydrogen and water in oil,
- two N14 devices, for measurement of currents, voltages, power on both sides of autotransformer,
- ADAM5510, for monitoring of tap changer operation,
- Qualitrol 509-300, for control of radiators and monitoring of tap changer operation,

Connections and exchange of data between components of the whole monitoring system is shown in Figure 4.

11. Conclusion

The monitoring system of autotransformer was installed and now is used in the Poręba and Bieruń substations. The view of the assembled system is show in Figure 3. Looking from the top left of the picture we can see: Ethernet switch, 24 V power supply, ADAM500/2 controller (ADAM500/1 does not fit in the image frame), below: Pt100 converters, 24V power supply, ADAM 5000, WAGO controller, group of relays.

References

[1] Project of AT1 transformer monitoring system AT1 in the Poręba substation.