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THE MEASURING SYSTEMS CONSTRUCTION AND POSSIBILITIES OF THEIR SOFTWARE SOLVING

KONSTRUKCJA SYSTEMÓW POMIAROWYCH ORAZ SPOSOBY ICH REALIZACJI PROGRAMOWEJ

Abstract: The on-line monitoring is ever more frequent at diagnostics of machines, which have a strategic importance or their breakdown would means a big financial losses. The paper is focused on the theory of monitoring systems constructions. Individual steps of realization are described - the selection of methods, data acquisition, diagnosed machine and measuring system connection. The selection of watched parameters suitable for diagnostic investigation is approximated on power transformers on-line monitoring.

Streszczenie: Tak zwany monitoring on-line (ciągły) maszyn o strategicznym znaczeniu lub takich, których awaria spowodowałaby znaczne straty ekonomiczne jest coraz powszechniej stosowany w diagnostyce tego typu maszyn. Niniejszy artykuł koncentruje się na teorii konstrukcji systemów monitorowania. Opisano poszczególne kroki projektowania i realizacji systemów monitoringu – wybór właściwych metod monitoringu, sposoby rejestracji i archiwizacji danych, sposoby sprzęgania systemu monitoringu z monitorowanymi maszynami, Odpowiedni dobór śledzonych parametrów w celu zapewnienia skutecznego diagnozowania stanu maszyny przedstawiono na przykładzie systemu monitorowania on-line stanu technicznego transformatora mocy.

1. Introduction

Systems based on continuous data collection are mainly usable in operations, where timely detection of beginning disturbance prevents from financially exacting repairs or in the operations, where the system shutdown causes a grave peril. There is no universal method for determination of actual state of monitored machine. The first task at all monitoring system construction is the selection of methods, which are sufficient predicable and which are possible to use for measuring in full machine run. Methods are selected according to kind of machine, for which the diagnostic system is designed. Using values exiting from measured tracked machine or values generated by the monitoring machine is necessary.

An important step in diagnostic process design is data acquisition and process control. It means transmission of measured quantities to numeric values and their storing or display. Producer, who completes the monitoring system about connection modules with signal conditioning, solves this problem in some intricate apparatus. In others cases it is necessary to solve problems with connection by other accessible resources.

2. Diagnostics process

The diagnostics is a branch of science dealing with data acquisition about object condition in the life-time. The main task of diagnostics is finding of unambiguous relation between change of decisive machine functional properties and some measured variable. The functional property change should qualify a level of status change and to specify, whether the status change is permanent or reversible process. Range and concrete construction of diagnostic system is the compromise between anticipated assembly costs, system costs and the estimation of savings incurred by break-down elimination, extension of service life. The determination of observed object diagnosis otherwise the determination of instantaneous technical conditions is necesarry to drow the concrete deductions about object condition. These deductions are frequently basis of decision making about next object life-time. The elimination of faults during burn-in procedure, the determination of instantaneous technical conditions and service life forecasting are the main tasks of diagnostic inspection in electrical apparatus operation. The technical conditions of diagnosed object are elicited from diagnostic signals that are information carrier about machine state. The diagnostic signals are either test signals (stimulative) or functional (operating signals generated by working object).

3. On-line monitoring

The non-destructive diagnostics is preferred and non-assembling one minimalizes additional cost. The functional diagnostics (on-line diagnostics) is unambiguously preferable, because operating signals generated by working object are used. The test signals are generated by diagnostic module in test diagnostics (off-line diagnostics) and object shutdown and measurement priming is usually required. On the other hand the functional diagnostics doesn't affect a regular machine running and it can be run continuously. So the advantage of on-line monitoring systems is continuous verification enabling a rapid response to change of measured (watched) parameter. The on-line diagnostics diagram is shown in Figure 1. From Figure 1 is perceptible, that operating signals α_j go to diagnosed object entry. The signals are transferred as control signals y_j and operating signals responses $\{R_j^+\}$. These signals are given over interference element to measurement instrument and to physical model. The evaluation block compares results of sub inspections $\{R_j^i\}$ with eventualities $\{R_j\}$ and $\{R_j^i\}$ generated by physical model. The diagnosis result is again formulated from comparing.

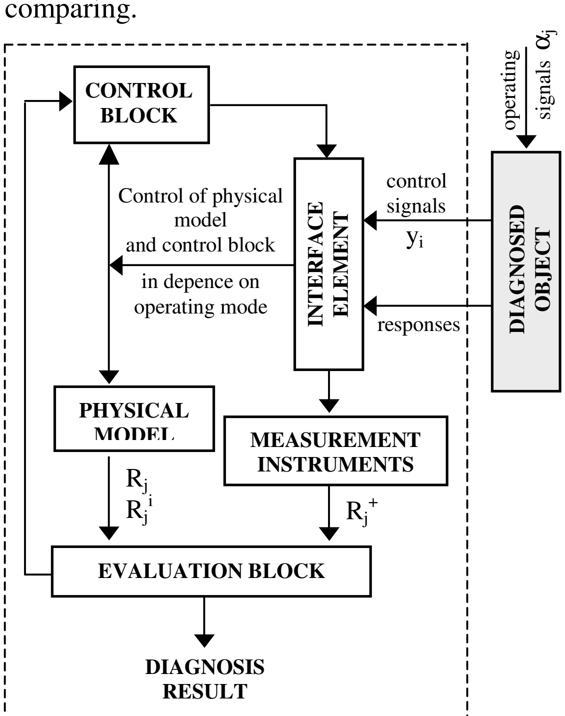


Figure 1: On-line diagnostics diagram.

The transfer function of diagnosed object is established for general description of mentioned diagnostics. The function represents dependence of output functions $Y = (y_1, y_2, \ldots, y_n)$ realized by diagnosed object on its input variable $U = (u_1, u_2, \ldots, u_n)$ and internal states $X = (x_1, x_2, \ldots, x_n)$ in time t.

For failure-free state is

$$Y = Y\,(\,U, X_p, t) \qquad (1)$$

where, Xp is initial value of internal variable – states.

For failure state is

$$Y_{pi} = Y_i\,(U, X_{pi}, t) \qquad (2)$$

where, X_{pi} is internal failure state.

The state of diagnosed object is detected by inspection $K = \{k_1, k_2, \ldots, k_n\}$. Inspection effects interact at inspection time – the effect α_j in sub inspection k_j – specified by input variable U_j in time t with initial value X_p. The diagnosed object response in sub inspection k_j is characterized by measuring points $\{\gamma\}_j$ and value – the result of sub inspection – dependent on object technical state R_j^i. The result of sub inspection, that is a function of effect α_i, is possible to formalize by sequence $\{\gamma\}_j$ - dimensional vectors. Is valid

$$R_j^i = Y_i\,(\alpha_j\,\{\gamma\}_j) \qquad (3)$$

and then is

$$R_j = Y\,(k_j) \quad \textit{for failure-free state} \qquad (4)$$

$$R_j^i = Y_i\,(k_j) \quad \textit{for object in i- failure state} \qquad (5)$$

Measured signals from sensors are obtained during the normal run of the machine or in special mode, usually limited operating mode. The functional diagnostic equipment is generally incorporated in watched object.

4. Selection of watched parameters

The selection of diagnostic parameters, which are simple measurable and predicable, is a next step in measuring systems construction. It is necessary to find out, which factors lead most often to a breakdown. It is usually a wetting of insulation and inception of electric or thermal failure in the case of power transformers.

The basic diagnostic indicator of failure-free transformer operation is an insulation state. The power transformer insulation is made from cellulose paper and transformer oil. This combination is very sensitive to degradation factors.

The testing of insulating paper is complicated therefore most diagnostic methods are for testing of insulating oil. The most important parameters indicating the state of insulation are gases dissolved in oil and partial discharge. Other factors affecting paper-oil insulation aging are temperature, moisture and oxygen.

4.1 Measurement of service properties

Basic service properties – electric current and phase voltage are measured by measuring transformers located in transformer bushing. The thermal load limiting transformer output and influencing insulation can be obtained from these properties. So temperature is the main limiting parameter for transformer loading and starting parameter for estimate of aging. Joule loss in winding, hysteresis loss and eddy-current losses share in heat formation. The heat stress is most caused by Joule loss that can be defined:

$$P_v = R \cdot I^2 = \frac{\rho}{\gamma} \cdot G_v \cdot \sigma^2 \qquad (6)$$

where

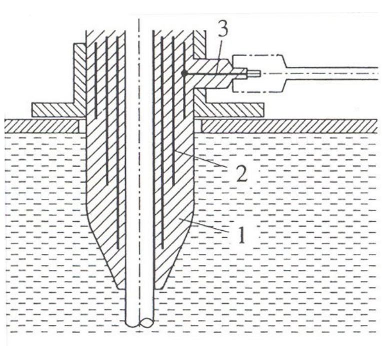
I - effective value of alternating current / A

G_v - winding capacity / m^3

ρ - electric resistivity / Ω·m

σ - current density / $A\cdot m^{-2}$

γ - specific weight of winding material / $kg\cdot m^{-3}$



1 - capacitor bushing
2 - semiconducting foil
3 - measuring terminal

Figure 2: Transformer bushing

This equation applies to primary winding as well as secondary winding.

The indirect temperature measurement is more frequent in practice and it is based on oil temperature sensing in top part of tank and measurement of transformer load current by means of heating resistor that is supplied by current proportional to transformer load current.

Stalk thermometer is used for oil temperature sensing in top part of tank, where the oil temperature is the highest.

The direct measurement is carried out by thermosensor with optical fibres and installed in winding. The optical fibre thermometers usually use a change in absorption spectrum of semiconductor GaAs in dependence on temperature. Disadvantage is a difficult installation into already running transformers.

For detecting of free gas in insulating oil a gas (Buchholz) relay placed between oil tank and dilatation tank is used. The measurement using Buchholz relay is intended only for quantitative determination of gas. Gas analysis using gas-liquid chromatography enables to identify and quantify individual gaseous mixture. Oil sample has to be analyzed in laboratory. Operating monitoring uses a special analyzer with selective permeable membrane. The analyzer can identify some dissociative gas (hydrogen H_2, ethylene C_2H_4, acetylene C_2H_2, carbon monooxide CO). Their presence and concentration point to the kind and relevance of breakdown. The sensors of analyzer are installed in cooler drain or tank valve.

Measurement of partial discharge shows deterioration of specific dielectric strength. An electromagnetic disturbance is the main problem at on-line partial discharge detection using electrical methods. That's why methods watching secondary effects accompanying partial discharge are better to use. Example of these methods is an acoustic probe scanning sound effects of partial discharge. The time interval of acoustic waves corresponds to partial discharge position. Software evaluation eliminates internal interference and jamming (for example oil circulation, mechanical noise) or external interference (corona, electric arc).

5. Data acquisition

Data acquisition and process control is one of the most important parts of measurement process. Raw data are acquired in this part of process. Measured values are usually converted to numeric value and saved in memory or displayed. Automatic measured data recording and its digital processing requires indirect measurement of physical values. These values are converted to electric value (commonly electric voltage) that is possible to digitize. The digitizing enables longer data transmission, digital signal processing and simple data and results recording. The sensors are instrumental to conversion of physical value to electric value. Because sensor is the first member of measuring

chain, sensor properties influence essentially an accuracy of measurement. These properties are especially a time stability and resistance to interference by another physical value, e.g. temperature. Sensor size is an important parameter for practical applications. The sensor miniaturization and its integration with preprocessing circuits and A/D converter are advantageous.
Present methods of data acquisition are:

- Plug-in multiple-function PC card
- Instrument with RS 232 interface
- Instrument with GPIB interface
- VXI Instrument
- PLC (Programmable Logic Controller)
- I / O systems

Using serial port (RS-232) or plug-in multiple-function PC card is optimal for realization of monitoring system with classical PC. The serial port (RS-232) is often used - over its disadvantages (low transfer rate – about 20Kbit/s, point-to-point connection, close range connection) – for low-price instruments, special measuring modulus, plotters.
The measurement system with plug-in multiple-function PC card is based on substitution of external bus for functional units connection by internal bus of control computer. The cards including D/A or A/D converters, counters, filters can be plugged in free bus slot. The multiple-function PC cards combine together multichannel analog inputs, analog outputs, pulse counters, digital inputs and outputs etc. The PC card inputs cannot commonly be directly connected to monitored equipment in most of industrial plants. Most producers complete plug-in PC cards with connection modules with signal conditioning.

6. Virtual Instrument measurement

For trouble-free sensor-to-computer communication it is often necessary to create so-called virtual instrument. It is the final product of the development environment integrating auxiliary tools for support of software application creation. The development environments picture classic controls, but they are not real. It is just visual display on computer monitor. Conventional and virtual instruments measurement comparison is shown in Table 1.
The philosophy of virtual measurement instruments is very progressive. The virtual instruments are software created so that they exactly correspond with user requests. This conception makes possible adding next user functions and their modification according to changing user needs. The price of these virtual instruments is usually lower than price of conventional analog measurement instruments. Most financial resources are spent on getting application software and PC card, but acquired development environment enables to create other applications or to modify existing one.

Table 1: Conventional and virtual instruments measurement comparison.

	Conventional instrument	**Virtual instrument**
Sequence on technological process	*slow reclaim time 5-10 years*	*fast reclaim time 1-2 years*
Development and service costs	*high bed cost / benefit ratio*	*low good cost / benefit ratio*

The virtual instrument reminds conventional one with behaviours and actions. Interactive graphical user interface (GUI), so-called Front Panel simulates the control panel of physical instrument and it includes controls and indications (buttons, controllers, LED displays, displays etc.). User operates this instrument with keyboard or mouse. The virtual instrument has a hierarchic and modular structure and it can be used like complete program or like its subprograms.

7. Measurement system software

Software plays more and more important part at computer - measuring instrument communication and has become the key point of measurement system. If the selection of hardware is perspicuous, the selection of software for data analysis and data visualization is necessary. Using standard programming languages (C language, Pascal, Basic) is time-consuming. Language syntax is difficult (an intimate knowledge of hardware design is required). These disadvantages could be eliminated by using CASE products (Computer Aided Software Engineering). There are many products at Development Environments category in the world market. For example:

- HP VEE -from Hewlett-Packard company (graphic programming in Windows)
- Test Point - from Keithley company (graphic programming in Windows)

- Control Web - from Alcor Zlín company (graphic programming in Windows)
- LabWindows for DOS - from National Instruments company (text-based development environment)
- LabVIEW - from National Instruments company (graphic programming in Windows for various platforms)

8. Conclusion

The present software market disposes of large quantity of diagnostic systems. We can find so-called closed diagnostic systems giving to user a limited quantity of functions programmed by their creators. On the other hand open systems can be extended according to user needs. They are created in suitable development environment and named virtual instruments. The virtual instruments thanks to their advantages are very perspective at monitoring system, thay are more and more popular at diagnostics of strategic units.In the measuring system construction it is necessary to consider which operating properties to monitor for provision of the best predictive ability at present technically simple data acquisition and unambiguous status evaluation. Using on-line monitoring system should result from real requirement of continuous machine monitoring and should respect an economical profitability of this diagnostic investigation.

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