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Methods of Multi-Parameter Diagnostics of Electric Equipment Condition Within On-Line Monitoring Systems

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Abstract

Provision of power equipment with on-line monitoring systems is a relevant and highly sought task. Designing up-to-date intelligent diagnostic systems requires development of methods for multi-parameter diagnostics (MPD) of the facility condition based on the total diagnostic features. As exemplified in a high-voltage oil-filled transformer, a list of jobs needed for generation of an effective diagnostic complex has been compiled. Trends for concentration of gases dissolved in transformer oil of the ladle furnace have been extrapolated. Time of matching the threshold values determining the facility conditions by these parameters has been forecast. Experiments have proved that a stationary on-line monitoring system enables disclosure of developing defects. At this, the use of stationary systems as fault indicators only is non-efficient both in the technical and economical terms. The paper substantiates the list of task to be solved when developing methods for MPD in the on-line systems. It is shown that condition diagnostics is most efficient at a complex estimate of independent and cross-correlated signals. The authors highlight possibility of extended application of the developed methods for diagnostics of any electro-technical systems, which data may be submitted as trends.

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Keywords: power transformer; technical conditions; monitoring system; multi-parameter diagnostics; methods; substantiation; tasks

1. Introduction

When operating power equipment, there is a need for continuous control of its technical conditions. This purpose is relevant for generators of thermal and nuclear power plants, equipment of sub-stations, powerful electric motors,

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high-voltage switching devices, etc. At present, an established trend is an introduction of stationary diagnostic systems at the power oil-filled transformers at prolonged lifetimes. Independent on the lifetime, this task is urgent for transformer of high-power arc steel making and ladle furnaces (furnace transformers). This due to the fact that they are operated under severe conditions caused by abruptly variable non-symmetric load during electric arc steel melting [2]. Furthermore, RUL switching, which occurs at network transformers a few times in a year, is performed at furnace transformers up to 1,000 times in a day.

A number of parameters characterizing the state of an active part, insulation, high voltage inputs, cooling system, regulator of changing the number of windings under load (RUL), etc. determines the transformer condition. In recent years, stationary on-line systems for monitoring parameters of high-voltage network and unit transformers are being developed and commissioned. A comparative analysis of domestic and foreign systems is provided in [3, 4]. The systems for continuous control of furnace transformer conditions are also operated [5, 6]. They are developed based on the diagnostic equipment by OAO Dimrus (Perm) and Kelman's MINITRANS device for continuous control of gases and oil humidity.

The stationary condition control system is based on outcome of all on-line tests carried out at the operating transformer in an automated mode. The benefits of these systems in comparison with periodic complex checks is in a prompt personnel notification on the developing faults at early stages. This enables solutions both on the tactic level concerning condition control and at the strategic one in terms of repair and re-design planning up to a complete unit replacement.

Monitoring system field experience has revealed a number of methodological issues. The main issue limiting diagnostic capabilities of the on-line systems is an absence of available engineering methods for determination of a current equipment state according to the total of measured values. Recording and storing data supplied by channels 8-10 are of low efficiency and do not enable actual estimation of technical state. That is why, the systems being implemented are generally used as fault signal indications based on each parameter only.

The above problem defines a promptitude for developing methods and algorithms providing an on-line estimate of facility condition according to the total of diagnostic features. Condition evaluation according to some controlled parameters is termed as a multi-parameter diagnostics in specialized literature. Evidently, the tasks of MPD shall be substantiated at an initial phase of method development; the complex of action aimed at their solution is also needed.

2. Problem statement

It should be noted that the issues of developing MPD methods based on on-line monitoring data are understudied at present. Thus, according to recommendations of the guidance of the Rosenergoatom concern [7], the following classification levels shall be assigned for each parameter: norm, norm with deviations, norm with significant deviations, deteriorated and pre-emergency condition. In other words, the registered parameters are standardized according to their severity for the diagnosed facility. In addition, this document provides condition estimation based on the results of periodical measurements only. Similar international standards IEC 60076-1, IEC 60076-3, IEC 60599 and IEEE C57.104-1991 do not contain any recommendations on condition estimation according to results of continuous signal measurement, too.

[8] proposes to summarize heat monitoring, oil chromatographic analysis, measurement of partial discharge performance and control of the loss-angle tangent (tgδ) at inputs within the MPD framework . Without detailed analysis of the publications, it should be noted that the first two control types are not used at stationary monitoring systems. Consequently, the proposed MPD variant is also based on periodic measurements of diagnostic features and cannot be used in the data systems. Foreign publications, e.g. [9–11], consider most methods of condition control currently in use. However, they do not provide recommendations on the MPD implementation at the on-line monitoring systems. It substantiates the need for methods of complex estimation of the electric equipment condition according to the total of continuously measured diagnostic features. Below is feasibility of development of these methods as exemplified by power transformer of the 26 MVA, 110 kV voltage class installed at the ladle furnace (LF) of the electric steel-making steel works shop of OJSC Magnitogorsk Iron and Steel Works (OAO MMK).