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AES-2006 NPPs with VVER-1200 UNITs as a new approach to display of information from technical diagnosis systems

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Abstract

Operator performance in the main control room (MCR) depends to a great extent on the form and amount of the information on the nuclear plant process status. An unstructured form of data display may result in an increase in the data processing time and in errors in the decisions made by operators. Convenience of the NPP data flow handling is given an increased focus but the process of supplying diagnostic data to operating personnel is neglected by both the developers of technical diagnosis systems and by the MCR interface designers. The paper provides an analysis of the upper-level information from technical diagnosis systems and presents requirements to respective screen forms and implementation options.

Keywords: VVER-1200; Technical diagnosis system; Diagnostic information; Hierarchical structure; Reporting; Screen form; Information noise.

Introduction

Technical diagnosis systems (TDS) of modern NPPs has come a long way of evolution from primitive systems with a small number of measuring channels and limited data processing capabilities to complex software and hardware packages integrating functionally diverse TDS systems. Thus, for example, the monitoring, control and diagnosis system (MCDS) designed for Novovoronezh II AES-2006 nuclear power plant includes systems for:

- vibration monitoring (VMS);
- loose object detection (LODS);
- acoustic leak monitoring (ALMS);
- leak humidity monitoring system (LHMS);
- residual life automatic monitoring (RLAMS);
- multipurpose diagnosis (MDS);
- integrated analysis (IAS).

Besides the TDS systems integrated immediately in the MCDS systems, there are autonomous systems for specific applications. Primarily, these are an integrated valve diagnosis system (IVDS) and an automated vibration diagnosis system (AVDS). It is planned that AES-2006 NPP with the VVER-1200 reactor will include a total of nine diagnostic systems operating based on similar but different algorithms.

Traditionally, the process of providing the NPP's operating personnel with diagnostic information is neglected both by the TDS developers and by the main control room (MCR) interface designers. Essentially, the problem consists in that operation of present-day TDS systems requires special knowledge in digital processing of signals, vibration dynamics of rotor machines, reactor physics and other fields operating personnel do not have despite being highly qualified. Moreover, most conclusions on the status of equipment are probabilistic, while the personnel responsible for running the process need exact answers to exact questions. The TDS developers design interfaces of systems based on the knowledge and the experience of technical diagnosis experts, while operating personnel are accustomed to receiving information in an absolutely different form. It is from this that the misunderstanding between the technical diagnosis experts and operating personnel arises, which often leads to conflicts. The notion "operating personnel" includes not only

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the MCR personnel but also operating personnel of the reactor department, the turbine department, the electrical shop, and the thermal automatics and measurement shop, as well as the personnel of the departments involved in the NPP process running.

Stages in the NPP equipment with technical diagnosis systems

To make it clear for understanding what will be said below, we shall look in brief at the history of the NPP equipment with different TDS systems. The authors conditionally divide the entire path of the TDS technology introduction, assimilation and operation into four stages.

The initial TDS evolution stage is peculiar in that NPPs lacked not only dedicated systems for equipment diagnosis but sometimes even tools for collection of respective information, leave alone online display of processed data on the equipment status. The diagnosis process often relied on enthusiasm of individual personnel.

As far as specific features of this stage are concerned, the diagnostic process, as applied to the conditions of Novovoronezh NPP, looked as follows (only vibration measurements are considered). Vibroacoustic sensors were installed on the monitored equipment (often one sensor for a component). The received signal was amplified, filtered and sent to the device that processed the electrical signal into a sound. If desired, the operator could choose the required channel selectively and “listen” to the operation of each equipment unit. And the defect was detected “by ear”. It is clear that one should be very cautious when speaking about accuracy or reliability of defect detection. Later on, with the advent of early, still primitive instruments for multichannel recording of signals (magnetographs) with a capability for fast Fourier transform (the basis of spectral analysis), it became possible to record and process data in laboratory conditions. In this case, naturally, one could hardly speak about online data display in any form.

At the second stage, Siemens TDS systems were purchased for technical diagnosis applications and partially adapted for operation at Russian NPPs. The systems were introduced at units 1 and 2 of Kola NPP, and at units 3 and 4 of Novovoronezh NPP. Since each system was designed to detect only one diagnostic symptom (e.g. an increase in the acoustic noise in excess of the threshold value could signal of a potential leak), this class of systems started to be called local diagnosis system (LDS) [1–4]. Long-term operation of TDS systems with further upgrading of both hardware and software products has shown that these systems fully perform their functions. It should be noted that, despite an advance in the solution of technical diagnosis tasks, the problem of supplying operating personnel with information on the status of process components has never been solved. On the one hand, the TDS systems as such were fully closed systems, since they were originally intended not for transmission of data to external data systems, and, on the other hand, the very information structure of power units was very primitive and highly undeveloped. Therefore, the exchange of data between the TDS experts and operating personnel was in the form of paper-based reports, certificates and memorandums (notes).

The next important stage was the integration of the LDS systems into packages of systems. This could be observed in the designs of Kalinin NPP’s units 3 and 4, and of Rostov NPP’s units 1 and 2. It was there that the concept of the monitoring, control and diagnosis system (MCDS) appeared. For correct operation of their algorithms, the systems in the MCDS received information from the upper unit level systems, while simultaneously sending its operation results to the power unit network. However, as earlier, the display of the MCDS operation results was predominantly neglected. Information was often incomplete and not entirely understandable to operating personnel. Further, as an example, we shall consider the format of the TDS information display at unit 4 of Kola NPP (Fig. 1).

And, finally, it is planned that stage 4 will be implemented in the VVER-1200 AES-2006 design for Novovoronezh II.

The authors have reviewed the strong and weak points in the diagnostic data supply to operating personnel. However, prior to proceeding to the results achieved, it is required to look at the problems concerned with the scope and nature of the needed TDS information to be transmitted to operating personnel.

Requirements to diagnostic data for upper level

We shall formulate the key requirements to the TDS information supplied to the upper unit level.

Intuitively understandable display of parameters

It so often happens that “intuitive understandability”, as it is seen by developers, is not treated in the same way by end users. A very graphic example for one to understand this problem may be the fact that, with the advent of digital technology, designers tried to convert any instrument reading to a digital format. But, as has been shown by practice, vital to the operator is not the parameter value accurate to two or three places of decimals (as an example) but the position of the needle on the scale which unambiguously showed to the normal or, on the contrary, to an abnormal status of equipment. The realization of this fact has brought needle indicators back both to the modern aircraft cabins and to the operator rooms where instantaneous perception of information is critical to decision-making. Naturally, the needle positions on the scales are simulated by computers, but this in no way makes the perception of information less valuable.

Absence of information capable to mislead the operator

The amount of information displayed in the screen is referred to as screen density. Studies have shown that the smaller is the screen density, the more accessible and user-understandable is information, and, vice versa, if the screen density is high, this may hamper comprehension and adequate interpretation of information. It is important to identify the smallest possible amount of readings capable to give the largest possible amount of information. No unnecessary or inaccurate information should be displayed because this may be harmful.

Naturally, all of the available information may be displayed. But the question is: what for? First, all the same, the operator will