Testing of the ICMS input data diagnostic system at unit 1 of Novovoronezh NPP II

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Abstract

A real-time in-core monitoring system (ICMS) input data diagnostic system was tested for the first time during the commissioning of Novovoronezh NPP II's unit 1. The system was developed by specialists of "Novovoronezhatomtechenergo", the Novovoronezh filial of JSC "Atomtechenergo", with participation of the Kurchatov Institute National Research Center's experts. The purpose of the diagnostic system development is to provide for the continuous monitoring of the input data validity in connection with the fact that new and upgraded ICMS designs include the performance of protective functions based on local in-core parameters.

Issues are formulated to be addressed in the development of the ICMS input data diagnostic system, the structure of the developed system is shown and basic data on its operation is given. The paper presents the key system test results which have confirmed that the system is capable to detect in real time the measuring monitoring channels with invalid readings and display respective diagnostic information.

The considered ICMS system may serve a prototype for the development of similar systems, to be completed with novel functions, in measuring channels of the NPP monitoring and control systems to enable an integrated real-time analysis of data for identification of the causes for, early detection and prediction of developing defects.

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Keywords: In-core monitoring system; Measuring monitoring channels; Diagnostic system; Invalid readings.

Introduction

Apart from information functions, the in-core monitoring system (ICMS) for new and upgraded NPP unit designs with VVER reactors also performs safety functions [1,2]. These functions consist in generation and transmission to the initiating part of the control and protection system (CPS) of preventive and emergency protection signals based on in-core local parameters such as the maximum linear power density per fuel element and the departure from nucleate boiling ratio (DNBR). This leads to greatly increased requirements to the ICMS maintenance activities, including periodic operational checks and tests, specifically for the validity of the input measurement data coming to the ICMS input [3,4].

The input data validity check is one of the most important primary processing functions in monitoring and control systems. The ICMS designs include functions for checking the input data validity but they are limited because they do not use to the full extent the structural features of data measuring systems and monitored processes. Meanwhile, data validity checking algorithms based on these features are applied extensively, in particular, in the ICMS physical tests during the NPP unit commissioning and operation [5]. Physical ICMS tests are full-scale tests conducted, subject to regulatory requirements, to confirm the functionality of the system and its compliance with the design characteristics.

Presently, the requirements to the use of online monitoring (OLM) technologies for the NPP instrumentation and con-

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trol (I&C) systems maintenance have already been actually defined [6,7]. Therefore, activities are under way and different methods and techniques are proposed to implement OLM technologies at NPPs [8–11], including for the VVER NPP ICMS [12]. With regard for these requirements, a real-time ICMS input data diagnostic system has been developed by specialists of "Novovoronezhatomtechenergo" (NVATE), the Novovoronezh filial of JSC "Atomtechenergo", with participation of the Kurchatov Institute National Research Center's experts. The development of the system was based on a large scope of experimental data obtained by the authors as part of the ICMS physical testing at VVER NPP units of different designs.

The first ever full-scale test of the developed diagnostic system was conducted during the commissioning of Novovoronezh NPP II's unit 1. The paper presents the basic details of the system, the results obtained and its potential uses.

Issues addressed in the development of the input data diagnostic system

The key objective of the input data diagnostic system development is the establishment of an automatic real-time diagnostic system. This requires the development and implementation of algorithms that make it possible to automate some of the procedures performed by attending personnel in the process of the ICMS periodic maintenance and status checking in accordance with operating regulations. The attending personnel actions during the performance of required procedures for their formalization and algorithmization involved the following steps:

– determination of the operating mode in which the reactor plant is;
– determination of the state that meets the input data validity diagnostics and checking requirements;
– checking and assessment of the parameter monitoring channels for the validity of readings which meet the diagnostic conditions in a particular reactor plant operating mode;
– output of required information messages to attending personnel on checking and diagnostic results;
– archiving of current diagnostic results.

The system shall start to perform diagnostic procedures which consist in assessing the validity of the measuring channel readings with the "hot state" or "reactor at low power level" mode when conditions are fulfilled for the primary coolant temperature monitoring channel checking with calculation of additive corrections. Channels for monitoring of general technological parameters can be also checked in this mode of the reactor plant operation, e.g., the pressure drop in the reactor coolant pump set (RCPS), the RCPS supply frequency, the RCPS power and others. During operation at over 10% of the rated power, conditions are already fulfilled for the channels to monitor the self-power neutron detectors

(SPND) currents and the parameters involved in the calculation of the reactor plant weighted average power.

All checks to assess the validity of the measuring channel readings need to be performed in stabilized states of the monitored facility proceeding from the statistical processing method used. One can find out if the stabilized state conditions are fulfilled using the selected stability criteria of typical parameters for each reactor plant operating mode.

The methods to assess the measuring monitoring channel readings for validity used in the development of the diagnostic system were tested repeatedly as part of the ICMS physical tests during the commissioning and operation of VVER-1000 units of various designs [5]. Dedicated software is used at the present time to process the test results [13,14]. For validity assessments, the presented system used operating algorithms of this software modified, however, for online applications.

Messages on detected invalid readings of the analyzed monitoring channels are displayed in a generalized format with color indication, this enables the system operation results to be easily perceived. Besides, there is also a format with detailed information on the analysis results for analyzing the causes for the invalidity.

Diagnostic system structure

The ICMS input data diagnostic system consists of a computer (laptop) connected to the ICMS via the local network. Fig. 1 presents a block diagram of the ICMS input data diagnostic system which provides for a graphic representation of the system and the interactions among its key components.

The computer is fit with the MS Windows 7 operational system and special-purpose software, Diagnostika SVRK, which is the key component of the system and consists of:

– the executable file Diagnose.exe;
– the BD_SVRK.accdb database with information on parameters and settings for processing;
– setup files of the *.ini and *.txt type for storing information on the reactor plant operating mode determination and the selection of the time interval for the calculation;
– diagram templates for the rapid plotting of dependences needed to analyze and assess the behavior of the monitored ICMS parameters;
– text files with stored data processing information;
– binary files – archives of the values obtained from the ICMS.

Diagnostic system operation

Following the receipt of data from the ICMS, the diagnostic system buffers it. The buffer operates based on the first-in-first-out (FIFO) principle and may have any size. Normally, 600 data deliveries are fair enough which corresponds to the time of the received data storage (10 min). This value is subject to change depending on the pre-commissioning results. Data needs to be buffered for checks on a set of values and not on point data.