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New generation refueling machine information and control system

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Abstract

The main distinctive feature in the creation of the new nuclear fuel handling complex at the Novovoronezh NPP is the deep integration of the information and control system (ICS) and the electrical equipment complex of the refueling machine (RM) into a single complex. The structure of the multi-level multi-processor and multi-network ICS provides high fault-tolerance and functional safety and fully corresponds to the principle of no single point of failure, even when operating in single-channel mode. Control of the RM during refueling is carried out with the participation of a human operator, who is supported by an intelligent interface. The operator makes decisions on certain actions to control the RM and the complex as a whole, monitors the control process and takes decisions on preventing abnormal or emergency situations.

In fact, the ICS is a distributed system that implements the entire control cycle and contains information, processing and control parts. In each part, communication devices realize data connections between the components on the entire graph or on a common bus.

The development result is a new generation RM ICS that differs from the existing ones by innovative methodical, algorithmic, hardware–software and design-technological solutions, which reduce the time and increase the safety of nuclear fuel handling in VVER reactors. At the same time, the introduction of the RM ICS increases the installed capacity utilization factor (ICUF) of the power unit by about 1.66%, which ensures additional electricity generation and supply for consumers.

Keywords: Information and control system; Nuclear power plant; Functional safety; Nuclear fuel; Refueling machine; Decentralization of control functions; Single failure; Human factor.

Introduction

At present, the Russian NPP power units (except for the Kalinin NPP, Unit 3) are using control systems based on obsolete computing means, the resource of which has been completely exhausted. Taking into consideration the design features of the refueling complex [1] and modern requirements for nuclear fuel handling operations in terms of control, monitoring and safety, an integral approach is required to the process of creating a unified fuel handling system at NPPs in accordance with the prescribed regulations. The main component of this complex is the refueling machine (RM), which is directly used for fuel handling operations at a shutdown and open VVER reactor during planned preventive maintenance [2,3].

The previous experience of creating RMs shows that, despite scrupulous compliance with safety requirements in designing and manufacturing equipment intended for nuclear hazardous operations, the control system, electrical equipment and mechanical parts were developed and manufactured by different organizations without proper mutual coordination, which subsequently led to unjustified time and, as a consequence, economic costs.

That is why the main distinctive feature in the design of the new nuclear fuel handling complex is the deep integration

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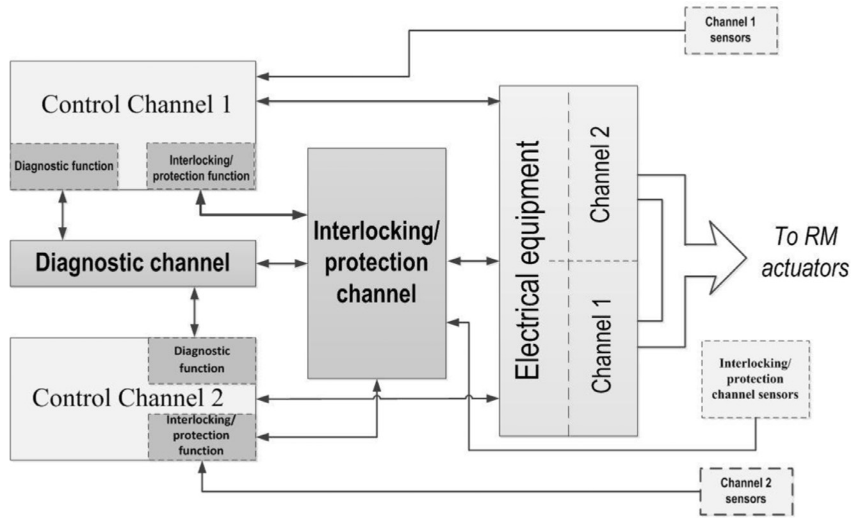

Fig. 1. RM ICS generalized structure.

of the information and control system (ICS) and the electrical equipment complex of the refueling machine (RM) into a single complex that takes into account all the constructional and operational features of the RM mechanical part [4]. This integration became possible due to the use of innovations in technical devices and technologies. First, there have appeared intelligent sensors that can be integrated into industrial sensory data transmission networks and reconfigured depending on the operating conditions. Second, modern frequency converters (inverters), in addition to direct engine control, have the ability to perform the function of controlling the local mechanism (drive) and be integrated into industrial control networks. New information technologies make it possible to use a combination of modern means and methods of collecting information to obtain new quality information about the condition of an object or process, algorithms for processing this information and taking decisions on controlling the RM on this basis. At the same time, it became possible to simultaneously take into account the RM condition for various and numerous groups of parameters, the control system hardware/software condition, etc., on a real-time basis.

The paper presents the conceptual design of the new RM ICS based on the latest achievements in producing hardware components and information technologies.

The ICS has a multi-processor distributed two-channel structure that ensures compliance with the fault-tolerance requirements in case of independent information and control functions. Intelligent software allows performing a real-time analysis and processing of incoming information from RM sensors, making decisions to prevent accident conditions during refueling caused by the personnel or technical failures, and predicting the initiation of subcritical or critical operating modes.

New RM ICS conceptual design

The most important requirements for the nuclear fuel handling procedures remain accuracy, reliability, and safety [5–9]. Therefore, for innovative Units 1 and 2 of the NVNPP II with a VVER-1200 reactor, a new information and control system for the RM was developed, manufactured, tested and implemented. This system has a multi-level multi-processor and multi-network structure (Fig. 1). This structure ensures compliance with the fault-tolerance and safety requirements, which fully corresponds to the principle of no single point of failure, even when operating in single-channel mode [10].

The ICS is built on the basis of modern industrial automation and computer facilities using new information technologies, the general tasks of which are as follows:

- Ensuring maximum functional safety in nuclear fuel handling operations and conducting maintenance and preventive works.
- Providing flexible equipment control.
- Providing optimal information support for the “human-machine” dialogue for efficient control.

The ICS, in general, operates in automated mode [11], since the process of controlling a complex technical object involves a human operator (one or more), who often decides on various actions to control the RM and the complex as a whole monitoring of the control process and makes decisions on preventing abnormal or emergency situations. The communication between the operator(s) and the ICS is carried out via the human–machine interface of the operator terminal.

The wide use of the function of automated decision support (Fig. 2) makes it possible to significantly undercut the influence of the so-called “human factor” on the control process, reduce the number of errors, and often exclude them when making decisions, i.e., improve the facility safety [12].

The functional safety principle is realized by the use of technical means localizing the development of unfavorable processes both in the ICS and in the RM in the event of faults and protecting the RM from issuing the wrong control actions to counteract the development of a dangerous failure and transfer the system to a protected state. For these pur-