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# IDENTIFIED DEFICIENCIES OF THE OLD GENERATION VVER-440 NUCLEAR POWER PLANTS PRIMARY CIRCUIT'S EMERGENCY PROTECTION SYSTEM

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This article addresses deficiencies in the existing primary circuit's emergency protection system, focusing on scientific and engineering issues related to outdated equipment, non-compliance with international standards, and the need for modernization. The primary challenges identified include obsolete instruments and sensors, which have become difficult to maintain due to the discontinuation of their production. Furthermore, the system fails to meet the requirements outlined in IAEA document TECDOC-640, OPB-88/97 regulations, and PBJA RU AS-89 regulations concerning redundancy, independence, diversity, recording, and archiving of parameters, diagnostic procedures, "single failure," and common cause failures. To address these shortcomings, the article advocates the complete replacement of essential equipment with modern digital solutions that fulfill contemporary requirements. Key reliability requirements include minimal downtime after sensor failure and swift maintainability.

The article underscores the necessity of replacing outdated sensors with modern counterparts capable of withstanding harsh environmental

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conditions. Ensuring failure-free operation after exposure to boric acid solution and other extreme conditions is crucial. The modernization project also requires the installation of two sensors for each measurement control panel, with separate measuring cable routes. Physical and galvanic separation of cable routes throughout the plant is emphasized, along with fire-resistant cables compliant with relevant standards. Metrological tests and a minimum measuring channel accuracy of 1.5% are also specified.

The article highlights the importance of avoiding common circuits between primary circuit's emergency protection and safety system actuation, calling for clear, well-lit parameter indicators. These indicators should enable independent settings of signaling actuation, inhibit unauthorized changes to set values, and fulfill environmental requirements.

The article additionally suggests replacing old indicators with new digital platforms, ensuring that they display digital parameter values and graphical changes.

***Keywords:*** *VVER 440, emergency protection system, old generation nuclear power plant, emergency protection system, safety system, nuclear safety, engineering analysis.*

The existing primary circuit's emergency protection system has some deficiencies:

- The existing designed equipment (instruments, sensors, etc.) is morally and physically obsolete and the production of it has already been finished. From this reason resulted the issue with spare parts and it was necessary to find the solution in modernization of I&C of primary circuit trip system

- The requirements of IAEA document TECDOC-640 (I&C 2 - Reliability of I&C equipment, I&C 3 - Control and protection systems interaction, I&C 4 - I&C redundancy separation and independence, I&C 7 - I&C and electrical equipment qualification, I&C 8 - I&C and electrical equipment classification) are not fulfilled.

- The requirements of OPB-88/97 regulation are not fully fulfilled from the point of view of redundancy, independence, diversity, recording and archiving of parameters, continuous and periodic diagnostic of operability, "single failure" and common cause failure.

- The requirements of PBJA RU AS - 89 regulation (section 2.3 Requirements for primary circuit protection system) for diagrams of creation of the primary circuit trip system signals and for safety system switching (sprinkler system, primary circuit emergency feed water system, etc.) have common circuits (common micro-switches, common relay, etc.)

The overall design of the primary circuit emergency protection system must be in compliance with OPB-88/97, PBJA RU AC-89, NP-031-01, TECDOC-640. I&C system of primary circuit emergency protection system from technological parameters must have the possibility of parameter archiving. All existing essential equipment of technological parameters control of primary circuit protection system operating in primary circuit protection formation have to be replaced with modern digital equipment, which fulfils the current requirements.

Reliability requirements:

Failure-free operation - time from failure of individual measurement - 10 000 hours minimally

Maintainability - average renewability - 1 hour

Requirements on sensors:

All existing original sensors for measurement of primary circuit technological parameters, which operate in circuits of protections and interlocks formation, have to be replaced with modern sensors calculated for conditions of surrounding environment in rooms, where are placed.

Measuring rooms A-004:

- temperature > 115 ºC
- overpressure to 0.2 MPa
- humidity up to 90%
- dose power $7.4x10^{13}$ Bq/$m^3$

All sensors must remain failure-free after intensive spraying by solution of boric acid with concentration 12 g/kg containing hydrazine up to 150 mg/kg and potassium ions up to 2 g/kg. Sensors for pressure measurement in main steam header installed in electrical length-wise building on floor +14.7 m have to meet these conditions:

- temperature 85ºC for 30 minutes (50ºC in long term)
- pressure 150 kPa in duration 30 minutes

- humidity up to 100%.

It is necessary to install two sensors for each MCP for measurement of technological parameters (two sensors for each MCP with the output signal from one equipment into one channel of MCP automatics and into the second channel of MCP automatics. Also, it is necessary to replace all measuring cable routes for mentioned sensors with the new cables. The primary sensors will be divided into the rooms in accordance with principle of "correspondence to channel". All measuring channels must be subjected to metrological tests in compliance with valid normative technical documentation. The accuracy of all measuring channels must be at least 1.5%.

It is necessary to consider the physical and galvanic separation at project realization of cable routes. All measuring cables have to be fire-resistant in compliance with standards GOST 12.1.004-85 and VSN-01-87 and PNAEG-9-027-01.

All cables must be resistant to the effects of environmental conditions. At project realization of cable routes, it is necessary to consider the physical and galvanic insulation to the maximum possible extent for the entire ANPP.

All measuring cables must be resistant to the effects of electric and magnetic fields. All measuring channels must be subjected to metrological tests in compliance with valid technical documentation. In the set of project documentation must be inserted the programs and methodologies of complex inspection of measuring channels.

The relay circuits of signals for actuation of safety systems, which begin with relay contacts in instrument, may not have the common circuits with the primary circuit emergency protection.

Indicators must have in front panel highlighted value of measured parameter.

Indicators must have 4 independent set values of signaling actuation and must be the possibility of inspection of set value actuation separately.

Indicators must have the inhibition of illegal change of set value of actuation and measuring range calibration. The corresponding LED must light in front panel and this diode will be switched off after operator`s command.

All indicators must meet environment requirements specified for main control room:

- pressure 80 - 107 kPa
- temperature 15 - 25ºC during the normal operation mode
- temperature up to 50ºC during the abnormal operation modes
- humidity 30 - 60%

Requirements for modern I&C of primary circuit emergency protection system include:

Primary circuit's emergency protection system shall be built on modern components and digital logic. The system shall consist of two physically and galvanically separated channels of primary circuit emergency protection.

The system shall have continual and automatic diagnostics of measuring channels and the recording and archiving of primary circuit measured parameters and separated circuits of creation of emergency protections from circuits of signals, which actuate the safety systems.

## CONCLUSION AND RECOMMENDATIONS

It is necessary to perform the separation of future cabinets of the primary circuit's protection system. It concerns the circuits of creation of protections and interlocks as well as the output relay. It is not admissible to leave the cabinets of both channels of the primary circuit protection system in one room. Hence, the first channel of the primary circuit protection system will be realized in room 2SUZ-1 and the second channel remains in room 2SUZ-2, This principle is the same for case if the circuits of formation of protections or interlocks will be built either on relay construction or on computer technology. After modernization of EPS all cabinets/panels (for relays and for instruments) of two trains will be physically separated. Only panels 1AZ-1 and 1AZ-2 (Emergency Protection panels) will stay in the same room. After modernization two trains of EPS will be

separated on the power supply side. However, the system trains cannot be considered fully separated, because:

1) the mentioned 1AZ-1 and 1AZ-2 panels will stay in the same room.

2) for the connection of impulse lines of sensors of the second train T-joints will be used and no new cutting-in to the technological equipment in foreseen

3) for measurement of the temperature in the hot legs, two-element thermocouples will be used (two thermocouples belonging to different trains are placed in the same protection sleeve, they are separated galvanically, but not physically.

It is recommended to replace the old indicators with new indicators based on the digital platform. In the front panel of such an indicator the digital value of measured parameter and the graphical change of the corresponding parameter must be displayed. Indicators must have 4 independent settings of signaling actuation. These settings must have the possibility to work also at increasing and decreasing of parameter. The inspection of actuation of settings must be possible separately. The corresponding LED must light in front panel after actuation of signal and is switched off only after operator's command. All secondary instruments must be specified for parameters of MCR-2 environment.