IMPULSE

SRPA «IMPULSE»

HIGHLY-RELIABLE INSTRUMENTATION AND CONTROL SYSTEMS FOR NUCLEAR POWER ENGINEERING

2026

The growth of the global economy requires ever-increasing volumes of energy consumption. Low-carbon energy sources, including nuclear power plants, play a significant role in the structure of generating capacities. Global nuclear energy also plays a crucial role in the ongoing mitigation of climate change. According to the latest IAEA forecasts, under the optimistic scenario, global nuclear capacity will double by 2025.

The core products of SRPA “Impulse” are instrumentation and control systems (I&C systems) for nuclear power plant units, based on in-house developed automation hardware and software. Together, these I&C systems ensure the implementation of all control and safety functions of NPP units, including:

- automatic and remote control of process systems under normal operation;
- monitoring of neutron-physical and thermal-hydraulic parameters of the reactor primary circuit;
- measurement of reactor neutron power and reactivity;
- identification of initiating events leading to deviations from normal operation, and control of unit safety systems;
- reactor power reduction and shutdown based on signals from preventive and emergency protection systems;
- monitoring of the technical condition and operating modes of process equipment;
- monitoring of safety parameters and the condition of reactor systems during design-basis and beyond-design-basis accidents, including accidents involving severe fuel damage;
- collection, processing, and storage of information on: deviations from normal operation, accidents and their progression; actual operating algorithms of systems important to safety; and personnel actions aimed at eliminating identified deviations.

The I&C systems are implemented on the basis of the MSKU 4M hardware and software platform, which includes PS5140 and PS5150 series workstations; MSKU 4 series industrial controllers; communication equipment; and software for various functional purposes.

SRPA “Impulse” is one of the few companies in the world possessing the technical solutions and technologies required to implement full-featured digital automated process control systems for nuclear power plant units.

Key Properties of the I&C Systems

Compliance with applicable Ukrainian, international, and national nuclear safety standards.

The equipment is manufactured in accordance with Technical Specifications approved by NNEGC “Energoatom” and the State Nuclear Regulatory Inspectorate of Ukraine. The I&C systems undergo the full scope of tests required by the regulatory documentation of the country to which the system is supplied.

Scalability and reliability.

These properties are ensured through a modular configuration that makes it possible to develop I&C systems tailored as closely as possible to specific project requirements.

Resistance to single, multiple, and latent failures.

This is achieved through redundancy and the use of diverse hardware and software sets.

Protection against cyber threats.

The software is fully developed in-house, with no hidden backdoors, and includes the use of data diodes and other protective measures.

Minimum number of cable connections.

Digital optical communication and remote controllers are used for remote control and signaling at control stations.

Possibility to modify design settings.

Operating personnel can modify design settings in accordance with established regulations and access authorization procedures.

Ease of operation and maintenance.

This is ensured by advanced self-diagnostics and the modular structure of the system, which allows faulty modules to be replaced without impact on system operation.

Continuous improvement and development.

The I&C systems are not only designed for decades of operation, but can also be flexibly expanded and upgraded using the latest technologies thanks to the Plug and Produce concept.

The systems are successfully operated at nuclear power plant units in Ukraine, Armenia, Bulgaria, Slovakia, and other countries.

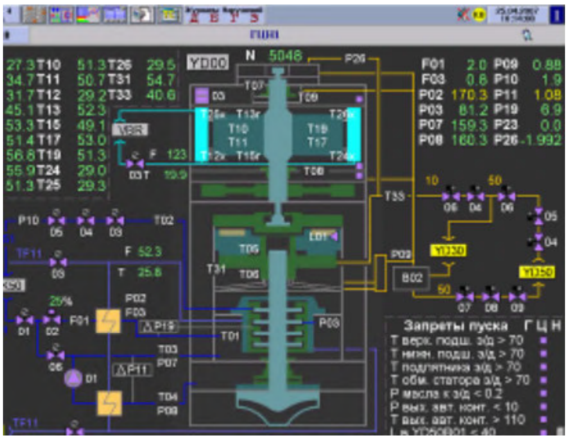
Main I&C Systems Manufactured by SRPA "Impulse"

- Process information system (unit's upper level);
- Normal operation control systems for reactor and turbine divisions;
- In-core monitoring system;
- System to monitor boron-10 isotope (boric acid) concentration;
- Safety control system technological;
- Neutron flux monitoring system;
- Control rod control system;
- Complex diagnostics system for equipment of a reactor facility's primary circuit;
- Accident and post-accident monitoring system;
- Standby diesel generator station automatic control system;
- Automatic regulating system of a turbine division;
- Turbine regulating system;
- System to record important operation parameters;
- Centre for technical support of operators.

PROCESS INFORMATION SYSTEM
(UNIT'S UPPER LEVEL)

The IVS process information system of a unit's upper level is one of the main components of an I&C system of NPP units.

Functions of IVS:

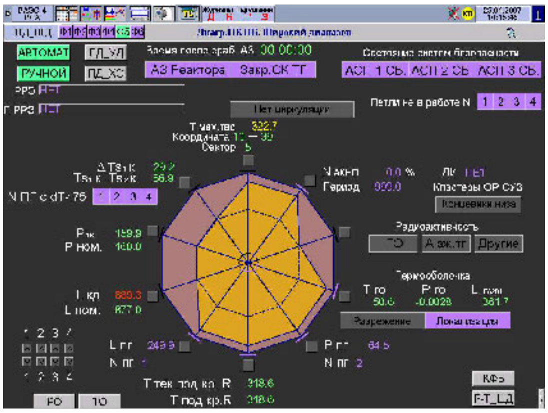


- providing information to personnel in an operating circuit of a main control room and local control stations;
- registering and documenting technological process parameters in all modes of operation of a unit;
- monitoring critical safety functions;
- monitoring basic safety parameters;
- providing recommendations as to equipment control in transient modes of operation of a unit;
- calculating and analyzing technical and economical parameters of unit's equipment;
- providing reference information about technological equipment and facilities of a unit's I&C system;
- calibrating measuring channels metrologically.

Composition of IVS:

- the lower level is implemented based on MSKU-4 failsafe industrial controllers;
- the upper level is implemented based on PS5140 industrial workstations.

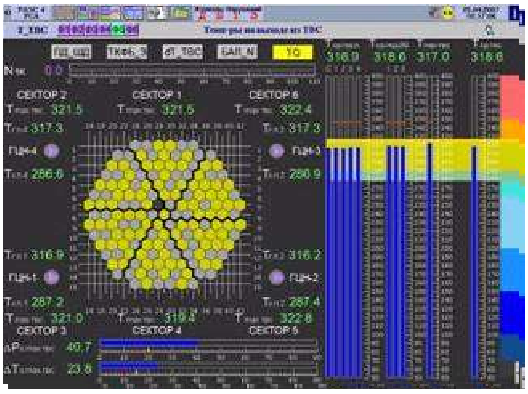
System advantages:

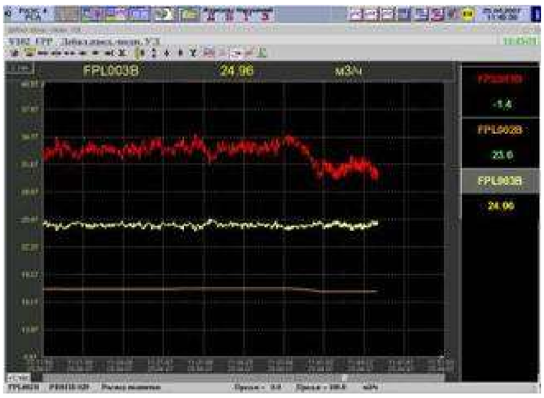


- possibility of step-by-step modernization of operating IVS systems with preservation of designed functions;
- built-in functions of a safety parameters display subsystem;
- implementation of unified protocols of data exchange with adjacent systems;
- wide list of additional functions, adaptation of control ergonomics to meet preferences of operating personnel;
- high degree of approbation of technical solutions due to a long-term experience of operation at NPP units;
- availability of built-in automated means for calibration of measuring channels.

Safety class – 3.
Safety category – C.

IVS equipment prepared for supply to NPP





IN-CORE MONITORING SYSTEM

The in-core monitoring system assures monitoring of neutron-physical and thermohydraulic parameters of a reactor facility's (RF) primary circuit and information support to an operator.

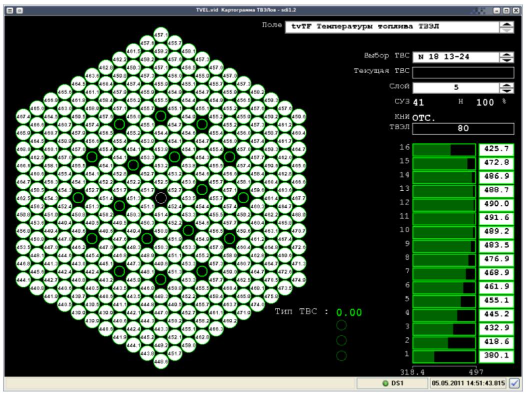
The latest modification (SVRK-M2) performs diversified calculations of neutron-physical parameters of the core using two software packages: the National Calculation Complex "ImCore" (SRPA "Impulse") and "Beacon-TSM" (Westinghouse).

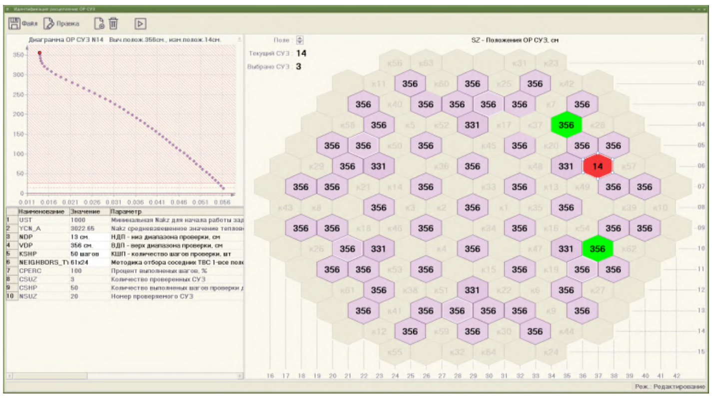
Functions of SGIU:

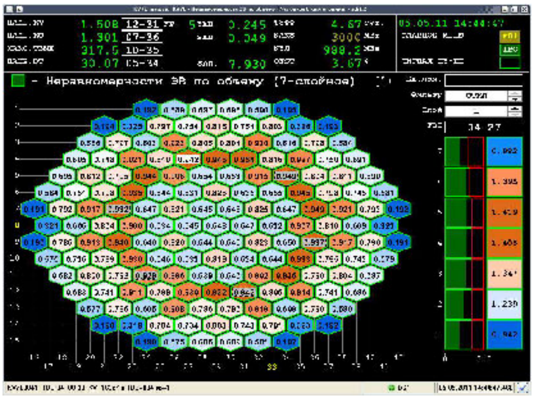
- monitoring of "mixed" loads with fuel of any suppliers including loads with fuel rod assembly of a different fuel rod height;
- monitoring of loads with fuel profiled in axial and radial manners;
- possibility to directly monitor linear power density at the fuel element level;
- electronic album of neutron-physical characteristics based on predictive functions of the system;
- informational support for an operator in power maneuvering modes.

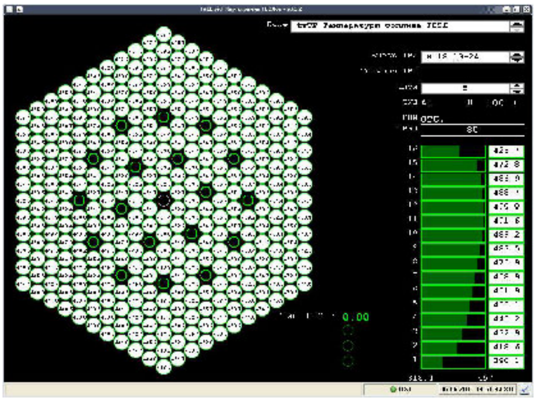
System advantages:

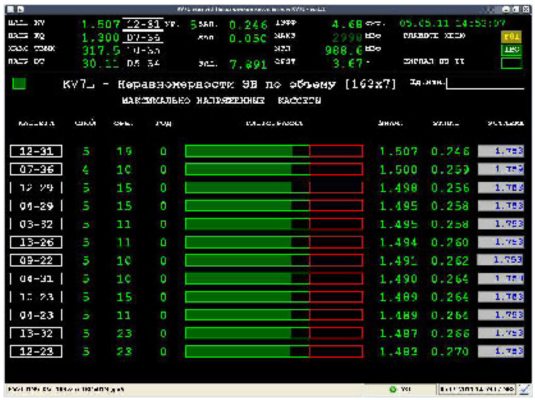
- Possibility to monitor neutron-physical and thermohydraulic parameters of a core in stationary and transient modes, including modes of power unit operation at increased power;
- Possibility to monitor cores with TVS-WR fuel manufactured by Westinghouse, including cores with "mixed" loads (modification of SVRK-M2 based on the complex "ImCore");
- Informational support for an operator to operate a power unit in power maneuvering modes;
- Possibility of implementation of new fuel cycles;
- High degree of approbation of technical solutions due to a long-term experience of operation at NPP power units..






Неравномерности ЭВ по объему (7-слойное)




Неравномерности ЭВ по объему [163x7]
МАКСИМАЛЬНО НАПРЯЖЕННЫЕ КАССЕТЫ

NEUTRON FLUX MONITORING SYSTEM

The AKNP-IF neutron flux monitoring system is a part of a control and protection system (SUZ) of NPP units.

Functions of AKNP-IF:

- monitoring, continuously registering, and archiving current values of reactor relative physical power, velocity (period) of its change, and reactivity;
- generating discrete signals on exceeding emergency and preliminary protection setpoints, setpoints of control and regulation by relative physical power and period for SUZ and unit's I&C subsystems;
- presenting analog and discrete signals in the optical and acoustic form to operators of main, backup control rooms and a fuel reload machine, to operating personnel;
- automatically correcting neutron power measurements taking into account thermal physic and other parameters characterizing state of a reactor facility;
- monitoring fixation of in-core devices by results of neutron detector signal fluctuation analysis;
- monitoring subcriticality of a reactor facility.

Composition of AKNP-IF:

- two sets of AKNP-IF APZ-SKP for SUZ and a main control room;
- one set of AKNP-IF BCR for a backup control room.

Each set includes three independent channels of neutron flux monitoring. Each neutron flux monitoring channel consists of:

- detection devices containing:
  - detection units based on ionization chambers (for startup and operating ranges), on boron or helium corona radiation-resistant highly sensitive neutron counters (for an SKP fuel reload monitoring system);
  - amplification and digital conversion units;
- an accumulation and processing device;
- a device for input of power setpoints;
- registration and display units for a main control room and a fuel reload machine panel to display and archive current parameters, as well as to transfer information to unit's adjacent systems – common for three neutron flux monitoring channels.

Detection unit for start-up and operating ranges

Detection unit for SKP

System advantages:

- automation of calibration of neutron flux density monitoring channels during operation of AKNP-IF using a metrologically certified reactor kinetics simulator developed by SRPA “Impulse” (signals are simulated in a whole range of neutron flux monitoring without necessity of access to sensors in a restricted zone);
- high accuracy due to use of highly sensitive boron and helium neutron sensors;
- integration of a fuel reload monitoring system into AKNP;
- absence of influence of residual readings of detection devices after power operation due to use of fluctuation mode of an ionization chamber;
- possibility of operational calibration of power readings in MCR with automatic recalculation of calibration coefficients;
- high fail-safety of the system due to use of redundant hardware and diverse software.

Safety class – 2.
Safety category – A.

CONTROL ROD CONTROL SYSTEM

The SGIU control rod control system is an executive part of SUZ of NPP units.

Functions of SGIU:

- automatically controlling OR movement by signals of protections, an automatic power controller or by operator's commands;
- indicating current position and state of ORs in main and backup control rooms;
- registering, visualizing, and archiving parameters;
- transferring information to unit's adjacent systems.

Composition of SGIU:

- a control rod control subsystem;
- a protection command generation subsystem (using "unconditional logic");
- a subsystem for monitoring of OR position and for individual power supply of position sensors;
- a subsystem controlling drives with devices for power supply of drives;
- a power supply subsystem assuring guaranteed power, backup, and operative power supply;
- equipment of control rooms (a manual control panel, a computerized panel for operating supervision, and a set of position indicators for control rooms);
- a monitoring and diagnostics server.

System advantages:

- doubling of each channel of drive power control with "hot" reserve of protection and control functions due to automatic unstressed switching of drive control from a failed channel to a reserve one with retention of all control functions;
- control of different types of drives with possibility of their online switching;
- possibility of OR control in any mode of both manual and automatic operation control and also in RF protection modes;
- power supply of power equipment with direct current, which allows to exclude mechanical automatic reserve switching and assure unstressed switching from a main power supply input to a reserve one in case of a fail or voltage reduction at the main input;
- automated support of a physical experiment to check control rod effectiveness;
- a developed diagnostic system with determination and registration of step skip, slipping, jamming of a cluster;
- inclusion of a testing stand for SUZ drives into a supply set.

Safety class – 2.
Safety category – A.

SAFETY CONTROL SYSTEM TECHNOLOGICAL

The USBT digital technological safety control system for NPP units is designed to initiate actuation and control safety systems.

Functions of USBT:

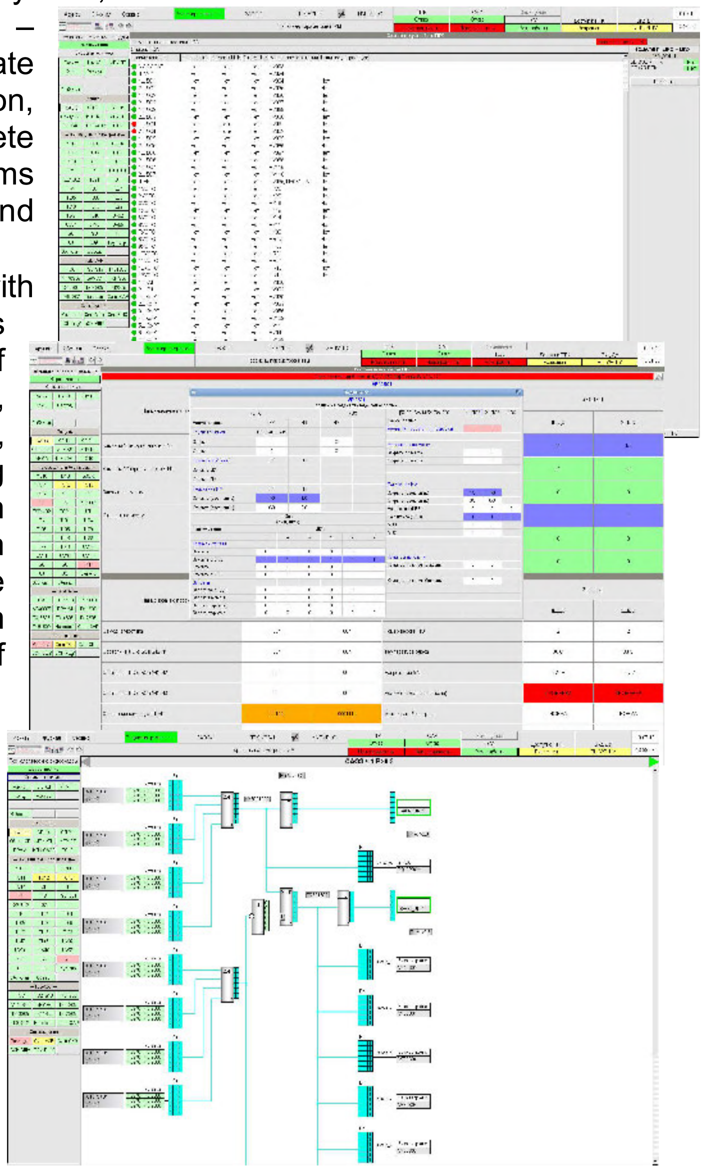
- monitoring technological parameters and identifying initial events by primary processing of input signals and generation of current signals in three mutually redundant MSKU channels;
- generating sequence of protective action commands by “2/4” logic that are stipulated for a detected initial event (protections of emergency core cooling system, pressurizer’s pulse valves protections, shut-down cooling protections, step-by-step diesel generator starting algorithms, etc.);
- generating technological protection and interlock commands by “2oo3”, “2oo2”, “1oo2”, “1oo1” logic (protections and interlocks of steam pipe and feeding pipe systems, main steam isolation valve, a technical water system, gas blowers, ventilation systems and conditioning, oil pumps, etc.);
- automatically regulating technological parameters;
- automatically controlling actuators;
- remotely controlling and indicating actuator state in MCR, BCR;
- generating technological and warning alarm signals in MCR, BCR;
- transferring data on technological parameter values, state of protections, interlocks, and actuators, diagnostic data to unit’s IVS;
- visualizing, archiving, and logging current data.

Composition of USBT:

- a subsystem of control and measurement instrumentation and current signal distributors – implements primary processing of input signals with assurance of redundant power supply of primary converters, generates current signals for external users (implemented based on industrial controllers of MSKU series);
- a control and switching subsystem – implements generation of sequence of protective action commands, commands of technological protections, interlocks, and alarm, as well as arrangement of internal information exchanges between USBT components via digital fiber-optical communication lines (implemented based on ShUK cabinets);
- an automatic regulating subsystem – assures generation of control actions for keeping technological parameters (pressure in steam generators, primary circuit cooling speed, level in steam generators in emergency modes, etc.) in accordance with specified regulating algorithms, monitoring of analog signal input channel operability, and realization of specified control algorithms in case of failures (includes MSKU SAR

implemented based on an MSKU industrial controller and an IS SAR engineering station implemented based on a PS5140 workstation). A SAR subsystem (automatic regulating subsystem) with equipment for communication with an operator's panel may be supplied separately as a SAR USB system;

- a subsystem of actuator control – generates signals of control and state of lock, air-operated isolation, regulating valves' actuators, discrete output signals to adjacent subsystems (is implemented based on ShDS and ShKr cabinets);
- a subsystem for communication with an operator – assures implementation of functions of remote control of actuators, indication of actuator state, technological alarm and warning alarm (implemented based on devices for communication with an operator's panel (USPO remote controllers in MCR) and alarm panels with a project based set of alarm annunciators);
- a technical diagnostics and archiving subsystem – assures reception, processing, visualization, archiving, and logging of data on state of technological parameters, actuators and data of technical diagnostics of USBT, adjustment of online changeable parameters, and transfer of current data to an upper level network of unit's IVS (includes diagnostic and archiving servers implemented based on a PS5140 industrial workstation).



System advantages:

- high tolerance to failures due to use of redundant hardware (MSKU three-channeled industrial controllers, redundant USPO, ShDS, ShUK cabinets and workstations);
- ergonomic and intuitively clear operator's interface;
- high level of system's security to cyber threats;
- convenience of operation and maintenance due to a modular structure of system's components with the possibility of fast swapping of faulty modules.

Safety class – 2.
Safety category – A.

STANDBY DIESEL GENERATOR STATION AUTOMATIC CONTROL SYSTEM (SDGS ACS)

SDGS ACS is one of the main parts of emergency power supply systems of all channels of a unit's safety system. SDGS ACS together with other adjacent systems assures control of startup, connection to a network and power operation of a DGU diesel-generator unit, control of excitation and protection of a generator, control of auxiliary equipment.

Functions of SDGS ACS:

- automatic maintenance in readiness and startup of DGU on receipt of commands fromthe safety control system;
- automatic, automated, and manual control of DGU startup/stop from controls;
- automatic maintenance of DGU power operation;
- emergency or normal stop of DGU on actuation of protections;
- control of equipment of a compressor plant and an air dryer package;
- continuous automatic archiving, warning, displaying, and recording of technologicaland electrical parameters, events, and states during operation of SDGS ACS;
- automatic emergency and preliminary alarm with generation of generalized signals ondisplay panels of MCR, BCR;
- transmission to unit's IVS of data on values of technological parameters, modes ofoperation of SDGS ACS, state of protections, interlockings.

System advantages:

- redundancy of equipment assuring functions of startup and maintaining DGU at power;

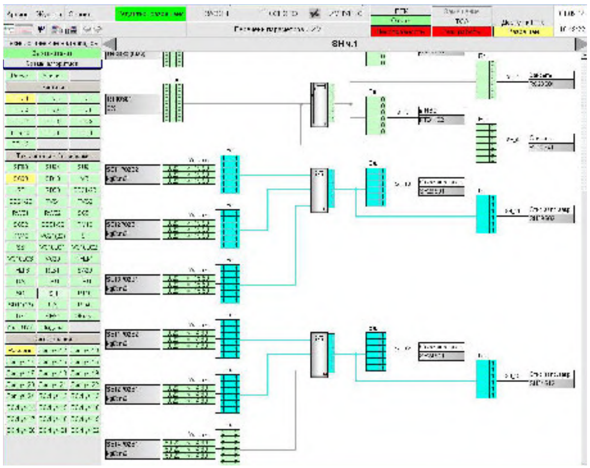
NORMAL OPERATION CONTROL SYSTEMS FOR REACTOR AND TURBINE DIVISIONS

The USNE RO, USNE TO digital normal operation control systems for reactor and turbine divisions are designated to implement functions of normal operation control of NPP units' technological systems.

Functions of USNE:

- primarily processing input signals and generating current signals;
- generating commands according to algorithms of technological protections, interlocks, and alarm;
- automatically regulating technological parameters with the possibility to change settings from a workplace of a SAR operator in MCR;
- remotely controlling and indicating states of actuators;
- visualizing, archiving, and logging of current technological and diagnostic information;
- transferring data on values of technological parameters, state of protections, interlocks, and actuators, diagnostic data to unit's IVS.

Composition of USNE:



- a subsystem of control and measurement instrumentation and current signal distributors;
- a control and switching subsystem;
- an automatic regulating subsystem;
- a subsystem to control actuators;
- a subsystem for communication with an operator;
- a subsystem for technical diagnostics and archiving.

Hardware, on which USNE RO and USNE TO instrumentation and control systems by SRPA "Impulse" are based, is analogous to hardware from the composition of USBT (except diverse sets) and has the same advantages.

Safety class – 3.
Safety category – B.

AUTOMATIC REGULATING SYSTEM OF A TURBINE DIVISION

Functions of ASR TO:

- automatically regulating turbine division technological parameters;
- functional-group control of a turbine regulating electrohydraulic system;
- remote control of actuators;
- interlocking regulators and control valves;
- technological and warning alarm;
- visualizing and archiving data on values of technological parameters, state of interlocks and actuators;
- transmitting data on values of technological parameters, state of interlocks and actuators to IVS.

Composition of ASR TO:

- a control subsystem – assures implementation of algorithms by interlocking and technological signalling functions with delivering control commands to equipment controlling actuators, as well as transmission of technological and diagnostic data to a diagnostics and archiving server (implemented based on ShUK control and switching cabinets);
- an automatic regulating subsystem (SAR) – assures implementation of algorithms of SAR and delivery of commands of SAR to the control subsystem (includes MSKU SAR implemented based on an MSKU industrial controller, an IS SAR engineering station implemented based on a PS5140 workstation, and an RM SAR operator's workstation in MCR;
- an actuator control subsystem – serves to control actuators of stop and control valves (implemented based on ShDS discrete signals cabinets);
- a subsystem for communication with an operator – designated to receive commands controlling indication from the control subsystem, transmit remote control commands from switches to the control subsystem, deliver actuator position indicating signals (implemented based on USPO devices for communication with an operator's panel);

RM SAR

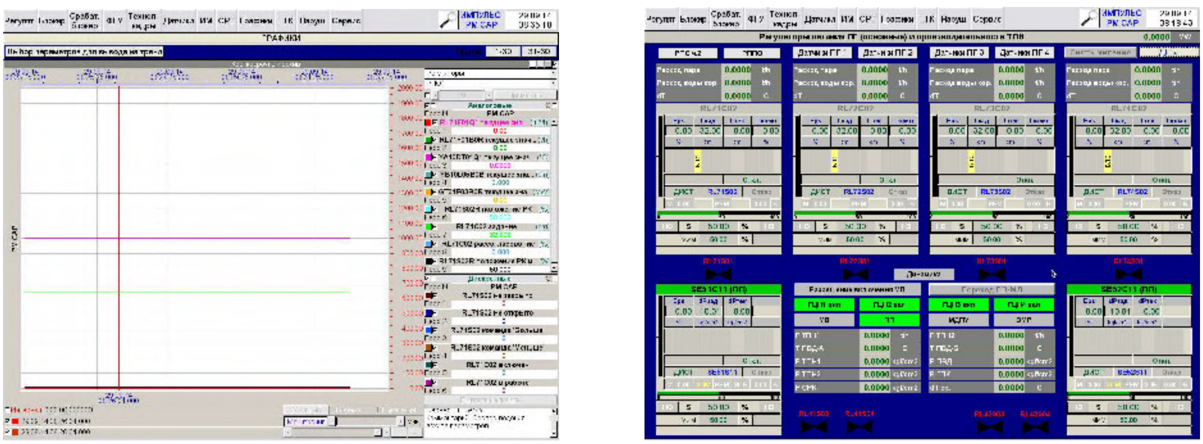
- a technical diagnostics and archiving subsystem assures receipt, processing, visualization, archiving, and logging of data on state of technological parameters, actuators and technical diagnostics data of ASR TO, as well as adjustment of quickly changed parameters (includes diagnostics and archiving servers implemented based on a PS5140 workstation).

PS5140 (ASR TO)

System advantages:

- high fail-safety due to use of redundant hardware (MSKU three-channel industrial controllers, redundant USPO, ShDS, ShUK, and workstations);
- implementation of data exchange between subsystems via redundant fiber-optical communication links;
- possibility of data exchange with I&C of USNE TO via a digital channel;
- ergonomic and intuitively clear operator's interface;
- convenience of operation and maintenance due to use of a modular structure of system's components with the possibility of fast swapping of faulty modules.

Safety class – 3.
Safety category – B.



Video frames of RM SAR

TURBINE REGULATING SYSTEM

Functions of SRT:

- automatically and semiautomatically rotating a turbine;
- synchronizing a turbogenerator (TG) with an electric network;
- loading or unloading TG with a rate specified by an operator;
- maintaining parameters of a turbogenerator at a specified level (rate of rotation – regulating accuracy not worse than ± 10 rpm, capacity – regulating accuracy not worse than ± 10 MW, steam pressure in a main steam collector – regulating accuracy not worse ± 0.5 kgf/cm^2) in starting and operating modes;
- assuring unloading TG in load-relief modes when technological protections of a turbine, reactor facility or protections of a generator are active;
- remotely controlling control valves of a turbine by operator's commands;
- performing the following protective actions:
  - preventing unacceptable increase in turbine rotation speed during load-reliefs;
  - changing a turbine over to idling or to auxiliaries while maintaining nominal speed after load-relief;
  - forming protection signals when acceptable turbine speed is exceeded;
  - limiting planned capacity changes.

ShERS-1

Composition of SRT:

- an ShERS-1 cabinet of an electronic speed regulator, a ShSRT-1 cabinet of a turbine regulating system implemented based on MSKU industrial controllers;
- a diagnostics and archiving server, an engineering station of an automatic regulating system implemented based on PS5140 workstations;
- RMO operator's workstations.

ShSRT-1

System advantages:

- reliable execution of safety electronic automate functions (maintaining a turbine at a power level available at the moment of failure of a main electrohydraulic regulating system);
- high operation speed (duration of a main operational cycle – 10 ms, time of response to discrete signals from emergency automation and signals of generator's switch position – not more than 5 ms, generation time for a signal "Protection by TG's rotor speed" from an initial event (change of frequency) – not more than 5 ms);
- possibility of supply within USNE TO, which reduces quantity of equipment due to use of workstations of USNE in SRT;
- possibility of operation in three modes:
  - using an electronic part of electrohydraulic regulating system;
  - using an electronic speed regulator;
  - in a manual control mode.

Safety class – 3.
Safety category – B.

COMPLEX DIAGNOSTICS SYSTEM FOR EQUIPMENT OF A REACTOR FACILITY'S PRIMARY CIRCUIT

Functions of KSD:

- deep complex technical diagnostics of main equipment of an RF's primary circuit using comparison and analysis of diagnostic information received from unit's instrumentation and control systems, local diagnostics systems, and own databases;
- providing a diagnostic engineer with centralized access to operating and archive diagnostic information received from different sources (IVS, local diagnostics systems, an automated radiation monitoring system, etc.) and allowing to determine and forecast technical state of operated RF's primary circuit equipment;
- transferring parameters to be displayed to a personnel to a unit's local area network.

Composition of KSD:

- KSD's upper level system including:
  - a redundant computing server of KSD based on two mutually redundant workstations;
  - a workplace of a KSD diagnostic engineer based on two mutually redundant workstations;
- SVRShD vibration and noise diagnostics system;
- SOSP loose parts monitoring system;
- SKPT system of RF's primary circuit coolant leakage monitoring;
- SVKD GCN system for vibration monitoring and diagnostics of reactor coolant pumps;
- SDOR fatigue monitoring system;
- SKPTr system of pipeline displacement monitoring.

Workstation

SVRShD vibration and noise diagnostics system

The system is intended for monitoring and diagnostics of vibration state of RF's primary circuit equipment, for monitoring of:

- trajectory of thermal displacement of RF's primary circuit main equipment in heating/cooling modes for detection of non-project displacement trajectories caused by defects in pillars of monitored equipment;
- vibration state of RF's primary circuit main equipment, including a reactor vessel, for detection of abnormal vibrations caused by change in pillar rigidity, weakening of equipment attachment points, or intensification of vibration causing powers;
- vibration state of fuel rod assemblies for detection of abnormal vibrations caused by weakening of attachment points or intensification of coolant influence;
- vibration state of a reactor shaft for detection of abnormal vibrations caused by wearout of attachment points or intensification of coolant influence.

Functions of SVRShD:

- inputting, converting, and comparing with setpoints signals from vibration sensors, vibration displacement sensors, neutron detection units, and direct charge sensors (possibility of reception of noise signals from all RF's DPZ sensors – totally 448 signals);
- receiving information on RF technological parameters from unit's IVS;
- archiving monitoring and diagnostic data;
- calculated diagnostics of vibration state considering current and archive data, generating reports;
- transferring information on state of diagnosed equipment to a computing server of KSD.

Composition of SVRShD:

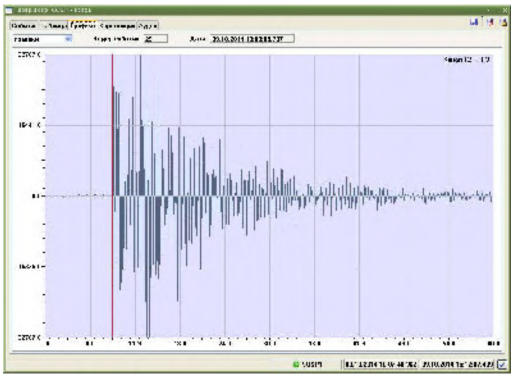
- piezoelectric vibration transducers, relative displacement sensors, detection units;
- neutron detector signal converters;
- measuring equipment based on AKSD.2 complex diagnostics system equipment;
- an SVRShD's computing server based on a PS5140 workstation.

AKSD.2

SOSP loose parts monitoring system

The system is intended for early detection and determination of loose parts and poorly fixed equipment details in coolant stream using acoustic sensors installed on the surface of RF's primary circuit equipment.

Functions of SOSP:

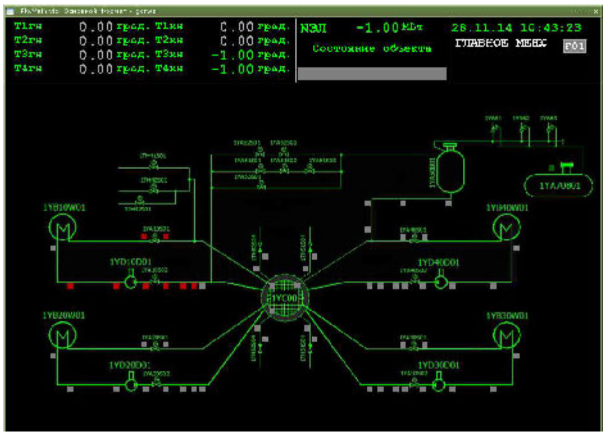


- inputting, converting, and comparing with setpoints noise signals from acoustic sensors;
- monitoring vessel noise of main equipment and RF's primary circuit pipelines, detecting loose and poorly fixed items (with the mass of 0.05 kg and more at the distance of 1 m from a primary transducer) in coolant stream;
- archiving data, listening and recording acoustic signals;
- monitoring operability of channels that receive and process signals of sensors;
- displaying diagnostics results to an operator and transferring to a computing server of KSD.

Composition of SOSP:

- acoustic sensors(piezoelectric vibration transducers);
- impulse hammers;
- a station for power supply of impulse hammers;
- measuring equipment based on AKSD.2 complex diagnostics system equipment;
- an SOSP's computing server based on a PS5140 workstation.

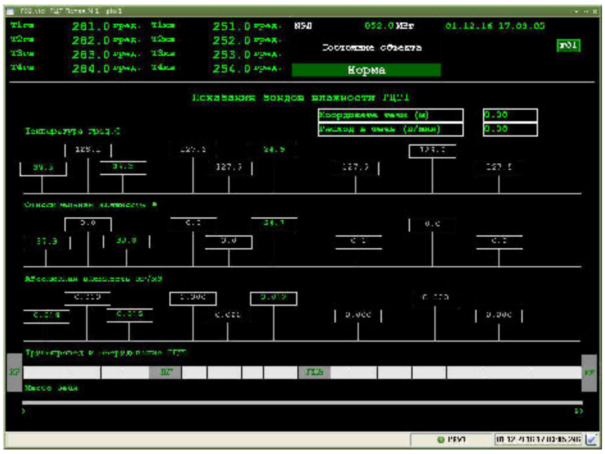
SKPT system of primary circuit coolant leakage monitoring



The system is intended to monitor tightness of equipment and pipelines of RF's main circulation circuit, to detect RF's primary circuit coolant leakage in time, to assess its magnitude in normal operation modes, with deviations from normal operation, and in a "small leakage" mode.

Functions of SKPT:

- inputting, converting, and comparing with setpoints signals from humidity and temperature sensors, acoustic sensors;
- receiving information from a unit's process information system;
- complex analysis on localization (with deviation not more than ± 2 m) and magnitude of a leakage with minimal registered coolant flow 1 l/min in the time period of not more than 10 min from the time of its actual occurrence;
- archiving data;
- displaying diagnostics results to an operator and transferring to a computing server of KSD;
- generating warning alarm.



Composition of SKPT:

- a subsystem of acoustic monitoring (PAK) including:
  - acoustic sensors;
  - measuring equipment based on AKSD.2 complex diagnostics system equipment;

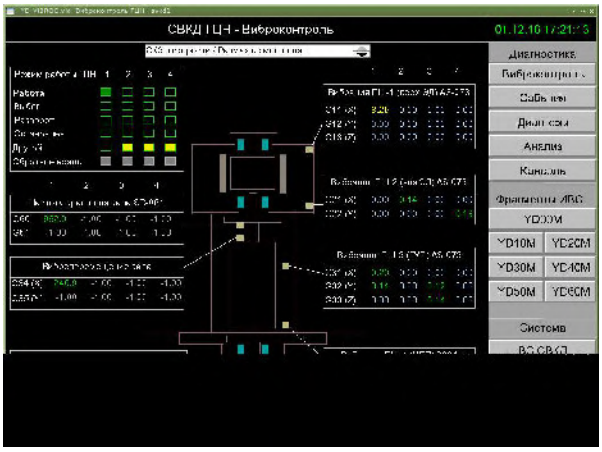
– an SKPT PAK's computing server based on a PS5140 workstation;

- a subsystem of humidity monitoring (PKV) including:
  – a relative humidity and temperature sensor;
  – measuring equipment based on AKSD.2 complex diagnostics system equipment;
  – an SKPT PKV's computing server based on a PS5140 workstation.

SVKD GCN system for vibration monitoring and diagnostics of reactor coolant pumps

The system is intended for monitoring of vibrational parameters of reactor coolant pumps (GCN) for early detection of abnormal states of mechanical and electrical parts, technical state forecasting based on complex analysis of vibrational characteristics and thermal parameters.

Functions of SVKD GCN:



- inputting, converting, and comparing with setpoints signals from vibration monitoring sensors;
- continuously monitoring GCN vibrational state and identifying slowly developed defects;
- monitoring vibrational characteristics in different modes of GCN operation, including rotor rundown mode during electric motor power supply shutdown;
- analyzing, archiving, and logging data;
- diagnosing GCN state with display of results to a diagnostic engineer and generation of alarm.

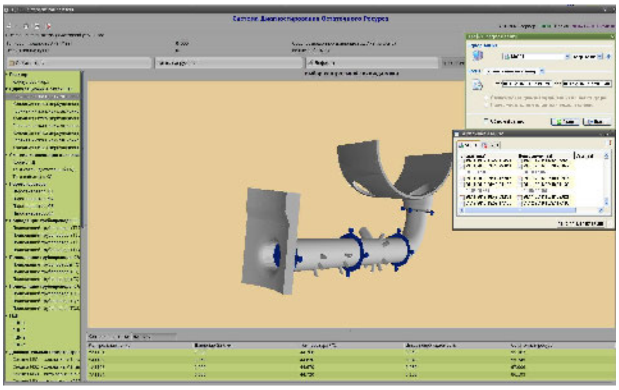
Composition of SVKD GCN:

- vibration monitoring sensors;
- primary converters of signals of GCN sensors;
- measuring equipment based on AKSD.2 complex diagnostics system equipment;
- an SVKD GCN's computing server based on a PS5140 workstation.

SDOR fatigue monitoring system

The system is intended to calculate cumulative fatigue damage dealt to metal in the most stressed points of a structure and to evaluate remaining lifetime of elements of main equipment of the RF's primary circuit (a reactor with a cover without in-core equipment, a pressurizer, steam generators, main circulatory pipelines, emergency core cooling system's and pressurizer's pipelines) based on continuous monitoring of thermotechnical parameters in different modes of RF operation.

Functions of SDOR:



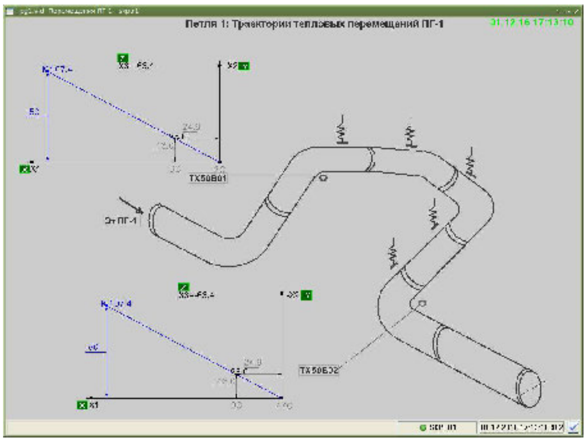
- inputting and converting signals from thermal control sensors (monitoring of thermal pulsations and coolant stratification), collecting and accumulating information received from a computing server of KSD;
- calculating fatigue damage and remaining lifetime in control (the most stressed) points;
- assessing remaining lifetime of equipment and pipeline metal;

- maintaining databases, registering signals received from IVS, KSD, and own sensors;
- providing information to operative personnel.

Composition of SDOR:

- temperature sensors (thermocouples);
- an I&C complex based on an MSKU industrial controller;
- an SDOR's computing server based on a PS5140 workstation.

SKPTr system of pipeline displacement monitoring



The SKPTr system is intended to measure continuously and to record maximum pipeline displacements under conditions of unit normal operation and transient modes (startup, stop, partial load decreasing) for provision of operating and technical personnel with information.

Functions of SKPTr:

- receiving and processing signals of three-axis displacement sensors, receiving technological signals of pressure and temperature in a steam generator;
- continuously remotely monitoring pipeline displacement by three mutually perpendicular axes and maintaining a database;
- providing an operator with pipeline displacement information as videograms;
- transferring information on displacements and violations of permissible displacement limits to adjacent systems;
- providing unit personnel with information on faults and failures, generating alarm on impermissible pipeline displacements.

Composition of SKPTr:

- a DTP three-axis displacement sensor;
- an I&C complex based on an MSKU industrial controller;
- an SKPTr's computing server based on a PS5140 workstation.

System advantages:

- consolidation of a wide variety of RF's primary circuit equipment diagnostic functions in a unified system while maintaining autonomy of local diagnostics systems;
- complex and reliable determination of RF's damaged or worn out equipment due to availability of local diagnostics systems with different methods of assessment of monitored parameters;
- time-tested diagnostic algorithms of KSD allow to assess intensity of damaging factors and to recommend on a reasonable basis deeper assessment of technical state of unit's elements and repair procedures considering current technical state of RF's equipment;
- construction and location of sensor attachment nodes on pipelines assure easy mounting and unhindered periodic monitoring of pipeline metal without accompanying dismantling of the attachment nodes;
- comfort of operation due to the ergonomic user's interface and a developed system for provision of operating personnel with current and retrospective information;
- use of unified hardware.

Safety class – 4.
Safety category of KSD – not classified.

"BLACK BOX" SYSTEM TO PRESERVE INFORMATION IN DESIGN AND BEYOND-DESIGN ACCIDENT CONDITIONS

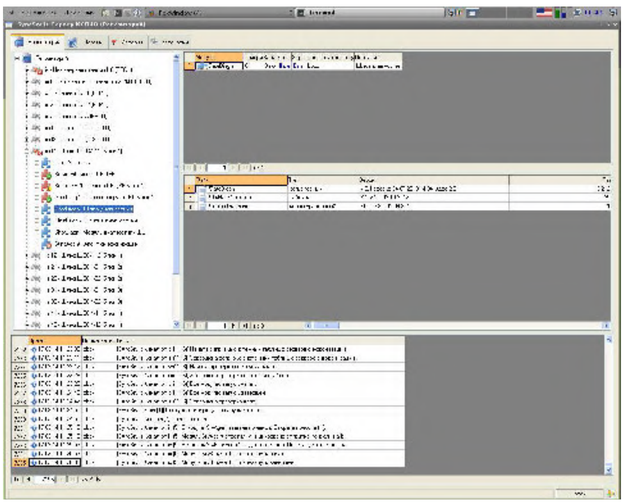
The "Black Box" system is designated to store and provide personnel with information on parameters of NPP units in accident and post-accident conditions of design and beyond design accidents.

Functions of the "Black Box" system:

- acquiring information from systems-data sources;
- registering and storing information in a long-term archive;
- providing personnel with information on parameters of NPP units in a form of diagrams and videograms.

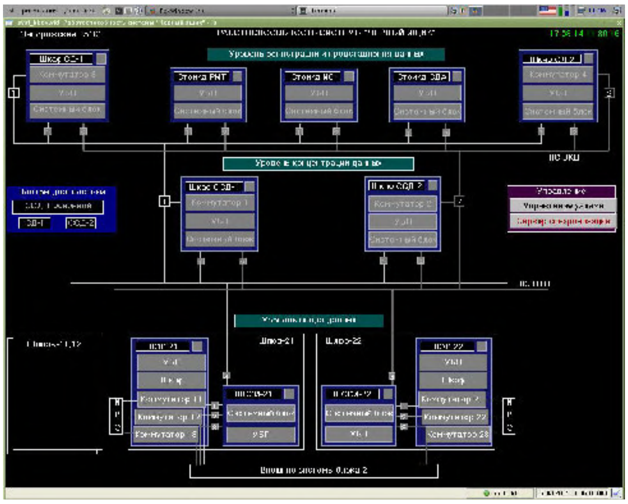
Composition of the "Black Box" system:

- a complex for registration and presentation of data received from a data concentration subsystem (KRPD), consisting of:
  - redundant data servers;
  - a server of a long-term archive;
  - a workstation of a technologist;
  - an engineering station;
  - hardware forming a radio channel for data transmission;
- a complex for concentration of data received from a data input subsystem (KKD), consisting of:
  - redundant data acquisition servers;
  - hardware forming a radio channel to transmit data to KRPD;
- a complex for input of data from systems-sources of unit data, consisting of:
  - redundant gateways for optical branching and communication, consisting of a gateway of communication with the source systems and an optical branching cabinet that assures receipt of data from external systems and transmission of signals to IVS and SRVPE (branching);
  - hardware forming a radio channel to transmit data to KKD.



System advantages:

- use of a highly-reliable approved radio channel for data transmission;
- implementation of data exchange between components via redundant fiber-optical communication links;
- high fail-safety of the system due to use of redundant hardware.



Safety class – 3.
Safety category – C.

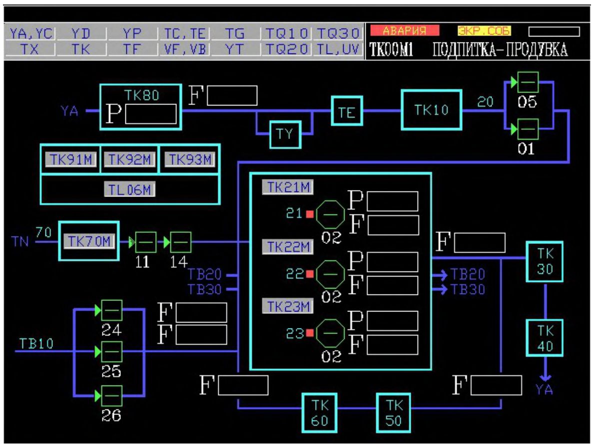
CENTRE FOR TECHNICAL SUPPORT OF OPERATORS

Functions of CTP:

- expert support of actions of operating personnel of MCR as to units control in an emergency mode and when liquidating accident consequences;
- monitoring a technological mode and forming recommendations as to its optimization at normal operation;
- receiving and processing information from adjacent diagnostic and information systems;
- providing operating personnel with information required.

Composition of CTP:

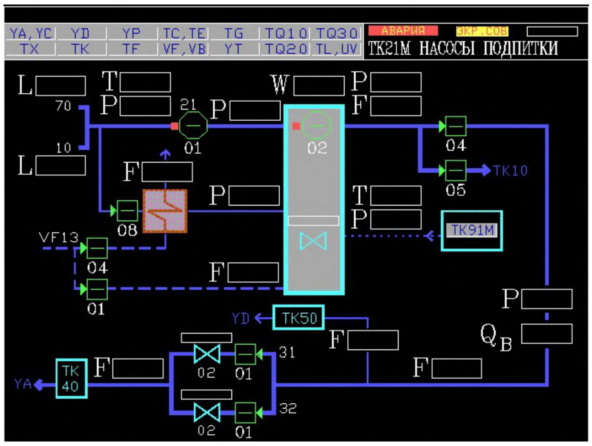
- I&C for information communication of CTP with adjacent systems and for presentation of state of unit parameters, consisting of:
  - engineering stations;
  - operator stations;
  - archiving servers of CTP;
  - a gateway for communication with an internal crisis centre;
  - portable workstations;
  - a remote viewing display;
- a complex of safety assuring facilities, consisting of:
  - radiation environment monitoring equipment (dosimeter-radiometer);
  - equipment for video surveillance of actions of operators of main and backup control rooms (video cameras, video recorders, communication equipment, video surveillance monitors).



System advantages:

- ergonomic and intuitively clear operator's interface;
- use of approved hardware and software solutions;
- high fail-safety of the system due to use of redundant hardware;
- continuous self-diagnostics of all components of the system with the depth up to a plug-in unit with generation of a warning on a fault.

Safety class – 4.
Safety category – not classified.



ACCIDENT AND POST-ACCIDENT MONITORING SYSTEM

The PAMS accident and post-accident monitoring system is intended for monitoring of safety parameters and state of reactor facility's systems during design and beyond-design accidents at NPPs.

PAMS implements functions of accident and post-accident monitoring at any design-relevant initial events, as well as beyond-design accidents (including those connected with severe damage of fuel).

Functions of PAMS:

- monitoring the following RF parameters with the use of emergency measuring instrumentation (AKIP):
  - level of coolant in a reactor – for level measuring thermoelectric transducers, located inside a case of an in-core direct charge detector assembly, are used;
  - level in a cooling pond – for level measuring sensor elements, based on the impulse reflectometry principle, are used;
  - temperature in a cooling pond – for temperature measuring temperature transducers with the measuring range 0 - 300 °C are used;
  - temperature in a containment – for temperature measuring resistance thermometers with the measuring range 0 - 300 °C are used;
  - containment radiation dose rate – for monitoring of radiation dose rate detection units (ionization chambers) with the measuring range 10^{-4} - 10^{5} Gy/hour are used;
  - pressure above a core – for pressure measuring pressure sensors of 0 - 25 MPa are used;
  - pressure in an accident confinement area – for pressure measuring pressure sensors of 0 - 1 MPa are used;
  - level in containment sumps – for level measuring differential pressure sensors of 0 - 70 kPa are used;
- providing operating personnel of NPP and emergency work headquarters with information on state of main safety functions and reactor facility's systems with the help of PAMS hardware resistant to emergency conditions, as well as data received from standard systems if they keep their operability;
- providing information on state and efficiency of protective barriers based on direct readings of AKIP when standard monitoring systems fail during beyond-design accidents;
- PAMS data transferring into the "Black Box" system and crisis centres.

Composition of PAMS:

- upper level of PAMS – MSKU industrial controllers and panel computers qualified according to application conditions;
- lower level of PAMS - emergency measuring instrumentation qualified for conditions of design and beyond-design accidents.

System advantages:

- high failure tolerance due to use of a distributed two-level structure with the use of two independent channels of data measuring, processing and displaying;
- use of hardware qualified for conditions of design and beyond-design accidents, including loss of coolant accidents (LOCA);
- use of AKIP with an advanced measurement range of monitored technological parameters of RF;
- assurance of PAMS operability under conditions of a maximum design earthquake and full blackout of a unit;
- reliable power supply of PAMS equipment due to use of a UBP-15 uninterruptible power supply assuring power supply for PAMS in case of unit blackout for a time period up to 8 hours.

Safety class – 3.
Safety category – B.

The main function of the NAR-I boron concentration monitoring system based on neutron solution analyzers – automatic continuous measurement of boron-10 (boric acid) concentration in coolant at NPP units with WWER-type reactors.

Composition of NAR-I:

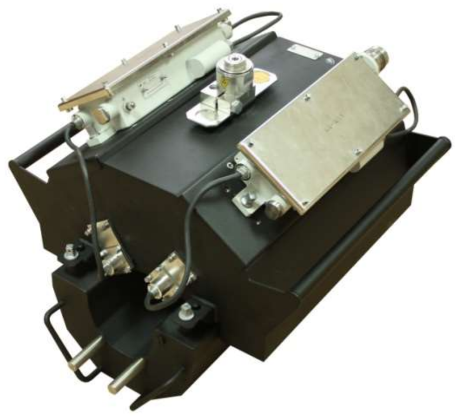
- main equipment – detection devices (sensors) and data conversion and processing devices (UPO) arranged as follows:
  - NAR-I-N – completed with a UDt-1N mounted sensor (is installed on technological pipelines);
  - NAR-I2-N – completed with a UDt-1N mounted sensor with lower radiation level;
  - NAR-I2-NE – completed with a UDt-2N mounted sensor (includes a hydrogen-containing material shielding from neutron radiation);
  - NAR-I-P – completed with a submersible sensor (is installed in tanks and reservoirs);
  - NAR-I-Pr1 – completed with a UDt-2Pr1 one-channel flow-type sensor with one cuvette connected with a sampling line to a technological system;
  - NAR-I-Pr2 – completed with a UDt-2Pr2 two-channel flow-type sensor with two cuvettes connected with sampling lines to technological systems;
  - NAR-I-K – completed with a UDt-2K control-type sensor (is installed in a laboratory room);
  - NAR-I-N-IS – completed with a mounted sensor and a symbol indicator indicating boric acid concentration in control rooms;
  - NAR-I-P-IS – completed with a submersible sensor and a symbol indicator indicating boric acid concentration in control rooms;
- additional equipment (forms a part of supply as an option):
  - Am-Be and Pu-Be fast neutron sources;
  - an InS symbol indicator;
  - an URO registration and display unit;
  - a ShT technological cabinet for UPO, URO installation;
  - a container to store and transport fast neutron sources.

UDt-1N mounted detection device

Assures measurement of boron-10 isotope (boric acid) concentration in pipelines with diameters equal to 89, 108, 133, 159, 325, 630 mm.

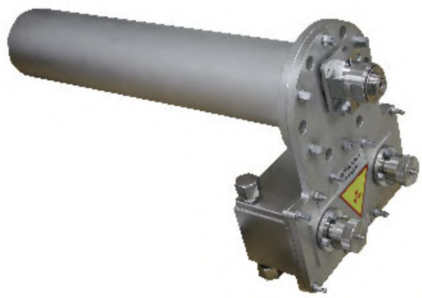
UDt-2N mounted detection device

Assures measurement of boron-10 isotope (boric acid) concentration in pipelines with diameters equal to 108, 159, 325 mm (separate versions of UDt for different diameters).



UDt-1P submersible detection device

Assures measurement of boron-10 isotope (boric acid) concentration in technological tanks and reservoirs with a protective sleeve with a diameter equal to 120 mm.



UDt-2Pr flow-type detection device

UDt-2Pr carries out measurement of boron-10 isotope (boric acid) concentration in sleeves connected with sampling lines to NPP technological systems.

Two versions have been developed: UDt-2Pr1 (one-channel version) and UDt-2Pr2 (two-channel version).

The technological part assures solution flow rate regulation, measurement of flowing solution parameters (pressure, flow rate).

UDt-2K control-type detection device

UDt-2K assures:

- measurement of boron-10 isotope (boric acid) concentration in working standard solutions used for calibration of working mounted, submersible, and flow-type boron meters;
- measurement of boron-10 isotope (boric acid) concentration in solutions with unknown concentration;
- determination of a boron-10 isotope atomic fraction in boric acid.

UPO conversion and processing device

Functions:

- calculating boron-10 isotope (boric acid) concentration;
- indicating values in digital and graphical forms;
- transmitting information via redundant communication links of RS-485 interface and as a current signal (0-5 mA or 4-20 mA) to external subsystems.

InS symbol indicator

Functions:
- indicating current boron-10 isotope (boric acid) concentration in a digital form on panels of control rooms;
- generating a warning alarm discrete signal.

Container to store and transport

A container certified by absorbed dose rate, which is designated to store and transport one fast neutron source (Am-Be or Pu-Be).

The container is manufactured as a cart with a frame (rigidly fixed on it), into which a removable container is installed.

URO registration and display unit

Functions:
- generating NAR-I archive;
- monitoring operability of all NAR-I devices of a unit;
- displaying archive data, including boron-10 (boric acid) concentrations in any technological point on a panel computer's touch screen;
- checking (calibrating) flow-type NAR-I.

To supply power to a panel computer an MPt power supply module is used.

Panel computer

MPt power supply module

ShT technological cabinet

Assures possibility to install and connect external communications to UPO or URO. Power cables and signal cables of UPOs are connected to strips of connectors of a ShT cabinet (cables from strips of connectors to UPOs form a part of the system).

Power consumption of ShT with four installed UPO doesn't exceed 160 W.

Protection degree of ShT – IP23.

NAR-I key metrological characteristics

Version	Concentration values, g/kg		Absolute error, g/kg		Concentration values, g/kg		Relative error, %
	boron-10	boric acid	boron-10	boric acid	boron-10	boric acid	
NAR-I-N	0÷0.192	0÷6	0.0048	0.15	0.192÷1.6	6÷50	2.5
NAR-I-P			0.0048	0.15			2.5
NAR-I2-NE			0.0058	0.18			3.0
NAR-I2-N			0.0067	0.21			3.5
NAR-I-Pr1	0÷0.32	0÷10	0.0032	0.1	0.32÷1.6	10÷50	1.0
NAR-I-Pr2			0.0032	0.1			1.0
NAR-I-K			0.00192	0.06			0.6

System advantages:

- high accuracy in continuous analysis of boron-10 (boric acid) concentration in process loops of NPP;
- small equipment readiness time after power-on (not more than 20 min) and output signal setting time by a single abrupt change of concentration (not more than 20 s);
- absence of additional errors of NAR-I because of influence of external factors (gamma-radiation with absorbed dose rate 0.22 Gy/h, temperature of external environment up to 90 ºC, temperature of measured solution up to 110 ºC);
- possibility to complete boron meters with Am-Be fast neutron sources with the life of 20 years;
- provision of possibility of NAR-I operation in accident conditions at temperature of external environment and solution up to 150 ºC (for mounted sensors at temperature of solution up to 265 ºC);
- testing-confirmed compliance with severe requirements of industrial standards for electromagnetic compatibility, environmental resistance, seismic resistance, vibration and shock loads.

Safety class – 2.

Safety category – A.

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