Federal Nuclear and Radiation Safety Authority of Russia
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Rules and Norms of Nuclear and Radiation Safety

REQUIREMENTS TO FULL-SCOPE SIMULATORS FOR USE IN TRAINING OF OPERATORS OF NUCLEAR POWER PLANT UNINT CONTROL ROOM

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REQUIREMENTS TO FULL-SCOPE SIMULATORS FOR USE IN TRAINING OF OPERATORS OF NUCLEAR POWER PLANT UNINT CONTROL ROOM

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This normative document sets forth main requirements to full-scope simulators as to a technical tool for training of the operating personnel of nuclear power plants and, especially , operators of nuclear power plant unit control rooms.

The aforementioned requirements are mandatory for all agencies and organizations that are developing and using the full-scope simulators for training of the nuclear power plant operating personnel.

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LIST OF ABBREVIATIONS

NPP – Nuclear Power Plant

ASC TP – Automated System of Control of the Technological Process

UCR – Unit Control Room

MCP – Main Circulation Pump

LCR – Local Control Room

ND – Normative Document

FSS – Full-Scope Simulator

SW – Software of FSS

IS – Instructor Station (the control panel of the FSS)

CPS – Control and Protection System

TMM – Training-Methodological Means

CCR – Central Control Room

MAIN DEFINITIONS

1. **ACCIDENT** – abnormal event in NPP operation resulting in a release of the radioactive substances and/or ionizing radiation beyond the boundary specified by the design for the safe operation and in the quantities exceeding specified limits of the safe operation.

2. **AUTOMATED SYSTEM OF CONTROL OF THE TECHNOLOGICAL PROCESS** - the system consisting of individuals (personnel) and the complex of means for automation of control of the technological process.

3. **NUCLEAR POWER PLANT** - a nuclear facility designed for production of the power in defined modes of operation and conditions of use, sited inside boundary of a specific territory , on which for this purpose there is used a nuclear reactor (reactors) and a complex of necessary systems, devices, equipment and structures with necessary staff (personnel).
4. **DATA BASE** - a set of design, calculated and experimental data on the reference power-unit which are used during construction and operation of a full-scope simulator.
5. **UNIT CONTROL ROOM** - a part of NPP unit situated on premises specially provided by the design and having purpose for centralized automated control of the technological process performed by operating personnel of NPP and means of automation.
6. **VERIFICATION OF MATHEMATICAL MODEL OF FULL-SCOPE SIMULATOR** - a procedure of confirmation, pursuant to established rules, of results of computation on full-scope simulator of static and dynamic operation modes of the reference power-unit by comparing them with experimental, design and calculated data.
7. **INSTRUCTOR OF FULL-SCOPE SIMULATOR** - an individual which has taken the full course of training and has got the right to train operating personnel of NPP.
8. **INITIAL CONDITIONS OF FULL-SCOPE SIMULATOR** - a set of values of parameters of full-scope simulator defining specific state of the reference power-unit from which a process of simulation can be started.
9. **COMPREHENSIVE TESTING OF FULL-SCOPE SIMULATOR** - a procedure of testing of hardware, models and software of full-scope simulator as a integrated complex in all range of simulated modes of operation and functions with aim to ascertain the compliance of full-scope simulator with technical specifications, with requirements of Normative Documentation, to check if the functions and training capabilities of FSS are implemented completely , to establish that processes on FSS are adequate to experimental and calculated data of the reference power-unit.
10. **DISTURBANCES OF NORMAL OPERATION OF NPP** – abnormal events in NPP operation resulting in deviations from established operating limits and conditions. Simultaneously there may be exceeded other, defined by the design, limits and conditions, including the limits of safe operation.
11. **NON-OPERATIVE LOOP OF UNIT CONTROL ROOM** - panels and consoles of non-operative control located out of area of constant monitoring from working places of the unit control room operators (beyond zone of direct visibility).
12. **OPERATIVE LOOP OF UNIT'S CONTROL ROOM** - panels and consoles of operative control located inside of area of constant monitoring from working places of the unit control room operators (inside zone of direct visibility).
13. **OPERATING PERSONNEL OF NPP** - operation personnel of belonging to staff of nuclear power plant, working in shifts and admitted to operating control of technological process at NPP.

14. **OPERATOR Of NUCLEAR POWER PLANT UNIT CONTROL ROOM** - an individual belonging to operating personnel of NPP which has taken the full course of training and has been admitted according to standing rule to the independent control of the power-unit.
15. **REPORT ON VERIFICATION OF MATHEMATICAL MODEL OF FULL-SCOPE SIMULATOR** - a report containing analysis of the results of testing and comparing of processes on FSS against experimental, design and calculated data.
16. **REPORT ON COMPREHENSIVE TESTING OF FULL-SCOPE SIMULATOR** - a report containing analysis of the results of the comprehensive testing of full-scope simulator (ascertaining of the compliance of full-scope simulator with technical specifications, with requirements of Normative Documentation, checking if the functions and training capabilities of FSS are implemented completely, establishing that processes on FSS are adequate to experimental and calculated data of the reference power-unit). To the report there must be attached the programme and results of testing, the report on verification of mathematical model of FSS
17. **TRAINING OF OPERATORS** - initial training or maintaining of level of operators qualification, which have working experience.
18. **MAINTAINING OF LEVEL OF OPERATORS QUALIFICATION** - maintaining of skills and abilities of operators in the control of unit by way of conducting regular training sessions on FSS using modes of normal operation and modes of abnormal operation, including pre-accident situations and accidents.
19. **FULL-SCOPE SIMULATOR OF NPP ENERGY UNIT** - a programmed-technical modeling complex intended for professional joint training of the operating personnel of NPP unit's control room with full-scale model of real unit's control room and complex all-modes mathematical model of the power-unit, functioning in real-time mode.
20. **PRE-ACCIDENT SITUATION** - NPP state characterized by violation of the limits or conditions of the safe operation but not developed into accident.
21. **LIMITS OF THE SAFE OPERATION** - defined in the design values of parameters of the technological process deviations from which may cause an accident.
22. **LIMITS OF MODELING** - boundary conditions of the power-unit status from/up to which the process of simulation of functioning of the technological systems and the power-unit in the whole is run.
23. **DESIGN LIMITS** - values of parameters and characteristics of the status of systems (components) and NPP in the whole defined in the design for the normal operation mode and for the abnormal operation modes including pre-accident situations and accidents.
24. **REAL TIME SCALE** - simulation of dynamic processes at the same relations against time, sequence, duration, rate and acceleration as in the real process.
25. **CURRENT STATUS OF FSS** - a set parameters values and statuses of simulated systems and equipment of NPP defining status of FSS at a given moment of time.
26. **TESTING OF FSS** - checking of FSS by way of computation of tasks on it results of which are known.
27. **OPERATION PERSONNEL OF NPP** - staff of NPP that carry out operation of NPP.
28. **REFERENCE POWER-UNIT** - the specific power-unit of NPP, identified as the basis for FSS design, including unit's design, commissioning and operation documentation.

1. GENERAL PROVISIONS

1.1. This normative document (hereinafter referred to as ND) sets forth main requirements to the full-scope simulator as to a technical tool for training of the operating personnel of nuclear power plants and, especially, operators of nuclear power plants unit control rooms.

1.2. The normative document defines minimal set of parameters and features of FSS necessary for effective training of operators of nuclear power plants unit control rooms.

1.3. Requirements of this ND are covering full-scope simulators of power-units of different types of nuclear power plants.

1.4. The requirements of this ND are mandatory for all design and engineering-design organizations that are developing FSSs, as well for operating organizations, training centers, training points using the full-scope simulators for training of the nuclear power plant operating personnel.

1.5. Requirements of this ND are covering also full-scope simulators developed on basis of foreign design and used for training of operating personnel of the Russian nuclear power plants.

2. SPHERE OF USE OF A FULL-SCOPE SIMULATOR

Main designated purposes of FSS are:

- initial training and requalification of the operating personnel;
- maintaining of the level of operating personnel qualification;
- accomplishing ability of operators of the control room to work in the shift;
- accident management training;
- accomplishing programmes and methodologies of training of the operating personnel; developing of programmes of new training lessons;
- training of instructors of training centers and training points and upgrading of their qualification.

3. GENERAL REQUIREMENTS TO A FULL-SCOPE SIMULATOR

3.1. FSS shall be designed in the way that allows to simulate the same situation as during operation of real facility and to exclude the acquiring by trainees of negative skills of control of the power-unit.

3.2. FSS shall be referenced to a specific power-unit (a reference power-unit).

FSS data base shall be consistent with the design, experimental and calculated characteristics and parameters of the reference power-unit.

3.3. FSS and organization of training on it shall ensure forming of practical experience, skills and abilities of operating personnel, working in the shift, in manipulation of the systems and equipment of NPP power-units functioning in normal operation modes and abnormal operation modes, including pre-accident situations and accidents.

3.4. FSS shall represent parameters of systems of the power-unit, corresponding to specific functioning conditions, to display these parameters dynamically in the real time scale on appropriate devices and ensure corresponding activation of alarm signals and protection systems.

3.5. FSS shall include:

- computer complex;
- input/output devices;
- units control room imitation (full-scale imitations of operational panels, consoles of the control room together with operative communication systems);
- instructor station (panel of FSS control);
- mathematical support and software.

Remark. When necessary it is acceptable to include in the FSS configuration non-operative panels of the control room and other control rooms (central control room, local control room, etc.).

Extension of simulation of equipment on FSS is determined on the case by case basis by the operation organization in the technical specifications for development of FSS.

3.6. In the process of training sessions there shall be made provision for automatic recording of the FSS instructor and trainee actions, activation of protection systems, interlocks, alarms, changes in the equipment functioning status, technological parameters of systems and equipment.

3.7. The design of FSS shall provide for possibility to upgrade and extend FSS functions, as well to modernize FSS when the reference power-unit is reconstructed.

3.8. FSS shall be procured complete with a set of training and methodological material, including methodology documents and programmes of training sessions for training and maintaining of the level of qualification of the NPP operating personnel.

3.9. Operating organization shall prepare and approve according to the standing rules the procedures necessary for timely implementation of appropriate alteration to the hardware, software and documentation of FSS when the equipment and system are modernized or when procedures of operation of the reference power-unit are changed.

4. REQUIREMENTS TO THE HARDWARE OF A FULL-SCOPE SIMULATOR

4.1. Requirements to the computer complex

4.1.1. Technical characteristics of the computer complex shall ensure modeling of the power-unit technological processes in the normal operation modes and abnormal operation modes in the real time and for some predetermined processes in the slow time and in the fast time.

4.1.2. The computer complex shall have necessary reserves of calculation speed, operative and external memory for the extension of functions, upgrading of mathematical models and modernization of FSS when the reference power-unit is reconstructed.

4.2. Requirements to the input-output devices

The information input-output devices shall have necessary reserves for the extension of functions and modernization of FSS when the reference power-unit is reconstructed.

4.3. Requirements to the simulation of Unit Control Room

4.3.1. The imitation of the unit control room of FSS shall comprise full-scale models of panels, consoles and the other equipment of the operative loop of the UCR of the reference power-unit together with belonging to them devices of monitoring, control, warning, communication as well fire-fighting means.

4.3.2. FSS shall include also equipment belonging to non-operative loop of the control room and necessary for realization of simulation of the operation modes defined in Section 5.

4.3.3 Control panels, consoles and other simulated devices of the unit control room shall replicate the size, shape, colour, configuration and functioning of those of the reference power-unit control room.

4.3.4. Apparatus located on the simulated panels and consoles of the unit control room shall replicate the size, shape, colour, configuration and functioning of the apparatus of the reference power-unit’s control room.

Slight deviations with regard to location and shape of hardware are acceptable if these deviation do not cause acquiring of false skill by the trainees.

4.3.5. An impact of the deviations of simulated control room of FSS from the real control room of the reference power-unit on the quality of training shall be evaluated for each specific deviation and include analysis of the following factors:

1) the differences in performing the operation procedure tasks on the FSS versus performing the analogous tasks at the power-unit;

2) the frequency of using of instrumentation and controls in the normal operation modes (i.5.3) and abnormal operation modes (5.4);
3) the differences in functions of equipment which has impact on NPP safety, on tripping the power-unit or damaging main equipment;
4) the difference in auditory and visual information presented to the operator, especially in critical situation in the power-unit control;
5) the differences in response of the instrumentation to manipulations of the controls by the operator;
6) the increase of probability of erroneous actions of the operators and the severity of impact of these errors on the safety of the power-unit.

4.3.6. The information on the power-unit operation mode shall be represented to the operator in the same format and the parameter units as at the reference power-unit, i.e. the FSS has to employ meters, annunciators , recorders, switching devices, light indicators, mimics, regulators and other devices, are identical with regard to external configuration and functions to corresponding devices and apparatus of the reference power-unit's control room.

The formats of presentation of information on the systems and equipment operation on the simulated displays of information-computing systems shall fully correspond to the formats of equivalent systems of the reference power-unit.

4.3.7. Automation means located on the panels and consoles of the FSS shall function in a such way that control functions performed by the operator shall produce the response of the simulator adequate to the response of the reference power-unit caused by control actions of the operator.

4.3.8. In the room where the simulator is located the conditions and operation environment of the unit's control room shall be replicated, where it has practical effects, with regard to, for example, lighting characteristic, air conditioning, covering and colour of the floor, turbine noise, floor plan and furnishing, temporary change of lighting during switching-on (off) of powerful electric power mechanisms, temporary blackout during loss of electric power, etc.

4.3.9. Communication means shall ensure the possibility of simulation of verbal communication of the operators of the unit control room with the operators of the local room and with operators working in another rooms of the power-unit, as well of exchange of information between the trainees and the instructor.

4.3.10. All deviations of external appearance of simulated unit's control room of FSS from the real unit's control room shall be justified in the FSS design.

4.4. Requirements to the Instructor Station

4.4.1. The instructor has to have a instructor station (a control panel of FSS). This station shall be equipped with the means of information presentation, of control and communication necessary for effective monitoring and control of the instructing and training processes.

4.4.2. The instructor station shall be separated from the simulated unit control room of FSS in the way that trainees will not be able to watch the instructor's actions (for example, by using tinted glass partitions).

4.4.3. The instructor station shall be located at a point that allows the best observation of the simulated unit control room of FSS.

The instructor shall be in position to conduct observation of the trainees' actions and to register their verbal communication and operating manipulations.

4.4.4. If the control of equipment, included in the scope of modeling, is to be performed at objects that are not included in the scope of modeling (non-operative panels of the UCR, Central Control Room, Local Control Room or «locally») then the control shall be carried out from the instructor station (the instructor acts in the capacity of personnel of the said objects).

4.4.5. The means of laud-speaker system and telephone communication of the FSS shall ensure possibility for the instructor to simulate operative verbal communication of the trainees with the unit's operating personnel external to the power-unit's control room.

4.4.6. The instructor station shall provide the capability to enter initial conditions of the power-unit, to conveniently insert and terminate simulated malfunctions (disturbances in the power-unit operation) as isolated ones as well multiple ones, in any combinations and time sequence, before the training session or during the session.

4.4.7. The control panel of the FSS shall provide the capability to enter new «tasks» (changing of set points and adjustments of systems in accordance with the operation procedure; disabling of changing of status of the equipment and controls, etc.). during the training sessions.

4.4.8. The FSS shall be able to perform the support functions of the instructor station:

- operative monitoring during the training session of the technological process simulation and actions of the trainees by employing the means of information display included in the FSS;
- storing and setting of the initial and intermediate conditions of the FSS;
- stopping of the process of model (freezing);
- changing of the time scale of the simulated process running (accelerating, slowing-down);
- storing and replaying of the training session process when it is necessary to the instructor;
- overriding control by instructor over manipulations of trainees with control switches, light indicators of the equipment status, warning tableau;
- recording of the commands entered from the control panel of the FSS.

5. REQUIREMENTS TO THE MODELING OF THE OPERATION MODES

5.1. General requirements

5.1.1. The FSS shall be capable of simulating the operation modes of the power-unit of NPP in accordance with requirements of the design and the technological regulations in the scope defined on the basis of requirements of the terms of reference of the FSS and this normative document.

5.1.2. The list of simulated modes shall be in conformance with the modes envisaged by the design of NPP the power-unit.

There shall be taken into account the experience in operation of the reference power-unit or the analogous power-units of another NPPs.

Specific list of the operation modes to be simulated on the FSS shall be defined in the FSS design.

5.2. Initial conditions

5.2.1. The FSS shall be capable of simulating the following main conditions of the power-unit;

- «cold» standby condition of the power-unit;
- «hot» standby condition of the power-unit;
- minimally controlled level of power;
- operation of the power-unit on power (0-100%) at different conditions of the simulated equipment.

5.2.2. The FSS shall have necessary number of stored in the computer memory initial conditions in order to be capable of transferring the FSS to any of the main conditions of the power-unit, described in i.5.2.1, for various times in core life (beginning, middle and end of core life). The specific list of initial conditions shall be defined in the FSS design.

5.3. Modes of normal operation

5.3.1. The scope of simulated modes of the normal operation shall be in compliance with requirements of the design and operating regulations of operation of the power-unit.

5.3.2. The FSS shall simulate maintenance work, performed during start-up, shut-down and operation at the rated power and intermediate power levels.

5.3.3. The minimal list of modes of normal operation simulated on the FSS shall include the following modes (taking into account specific technological scheme of the power-unit):

1) power-unit start-up from shutdown initial condition (loading of the core, filling up of the technological systems with working fluids and hydro testing are not mandatory to be simulated);
2) brining up of the reactor up to the minimally controlled power level;
3) conducting of experiments for measurement of the neutron physics characteristic of the core (in the scope of functions of the unit control room operators);
4) increasing of the reactor power with programmed rate;
5) turbine startup;
6) generator synchronization with the power distributing grid;
7) heat-up of the reactor facility up to the nominal parameters;
8) decreasing of the reactor load with programmed rate;
9) decreasing of the turbine load with programmed rate;
10) reactor trip and following recovery of the reactor from «hot» standby to the programmed power level;
11) decreasing of the reactor power to the subcritical condition;
12) cooldown of the reactor facility;
13) testing of the safety system channels and other systems being in the waiting mode;
14) testing of protections and interlocks by changing of model parameters or simulation of the output signals of sensors and instrumentation;
15) nuclear fuel reloading at power (in scope of functions of the control room operators of power-units with RBMK type reactor;
16) changing of the power-unit loading;
17) operation elements of startup, shutdown, power changing of the power-unit with less than full reactor coolant flow through the reactor (not all number of main circulation pumps being switched-on or loops coupled up);
18) power-unit shutdown from specified power to «hot» standby condition and cooldown to «cold» shutdown condition;
19) coupling up of non-working loop;
20) disconnecting of loops (main circulation pumps).

5.4. Modes of abnormal operation

The minimal list of modes of abnormal operation simulated on the FSS shall include the following modes (taking into account specific technological scheme of the power-unit):

5.4.1. Operation modes with reactivity changes:

1) random extraction (non-controlled movement) of a CPS control rod group combined with the least favourable conditions of the reactivity configuration;

2) «ejection» of a control rod;

3) drop of a control rod;

4) decrease of boric acid concentration due to the failures in system of the boron shim of the reactor power (for VVER type reactors);

5) unintentional ingress of cold water into the reactor (a faulty actuation of the emergency core cooling system of the reactor).

5.4.2. Operation modes with irregularity of coolant flow through the reactor:

1) closure of main isolating valve on the cold and/or hot part of leg;

2) trip of various number of the operating main circulation pumps in all possible combinations and during various modes of operation of the power-unit;

3) seizure of the main circulation pump;

4) break of the main circulation pump shaft;

5) failures in the system of control of check valves of the legs (for power-units with the fast breeder type of reactors – BN reactors);

6) drop in or failure of the water flow in one of the technological channels (due to spurious closure or failure of a isolation-control valve, ingress of foreign items) – for the RBMK type of reactors.

5.4.3. Operation modes with malfunctions in the feedwater delivery system:

1) emergency trip of the feedwater pump and failure of the redundant pump to switch on;

2) inadvertent closure of isolating valve at outlet of the feed-water pump;

3) failure of the regulator of the feed-water system;

4) loss of all feed-water (both normal and emergency);

5) emergency switching off of the high pressure heater;

6) malfunctions in the condensate feedwater channel.

5.4.4. Modes with switching off and failure of equipment:

1) actuation of the reactor protection system (manually);

2) drop in electrical load down to any level in the range from 0-100%;

3) turbine trip (all turbines);

4) generator trip (all generators);

5) loss of the vacuum of the turbine condenser;

6) loss of service water or failure of cooling of the technological system individual components;

7) malfunctions in system of heat removal from the containment;

8) malfunctions in regeneration systems of low and high pressure of the turbine;

9) opening and failure to shut down of the steam dumping devices;

10) malfunctions in the system of control of the pressure and volume of the reactor coolant;

11) loss of the coolant flow in the coolant channel of the reactor control and protection system (for power-units with RBMK and EPG-6 type of reactors;

12) malfunctions in operation of the Automated System of Control of the Technological Process, which cause faulty actuation or failures of system:

- unsanctioned opening/closure of isolating valves;
- unsanctioned switching on/switching off of pumps and failure of redundant ones to swish on;
- unsanctioned movement of working parts of the automatic control systems to open/closed position;
- failure of commands of regulators when there is disbalance of sensor and set-point device signals;
- failure of individual channels of parameter measurement;
- failure of individual subsystems of the Automated System of Control of the Technological Process, including information-computing system, core instrumentation system, fuel cladding integrity control system, etc.;

13) malfunctions in operation of the Automated System of Control of the Technological Process due to common cause (fire, earthquake, etc.);

14) loss of flow of secondary water, service water, circulation water;

15) malfunctions in systems of the residual heat removal;

16) malfunctions in operation of main equipment (valves, pumps, regulators, controls etc.);

17) cavitation flow-separation in pumps;

18) loss of gas in the loop of graphite stack cooling (for power-unit with RBMK type of reactors);

19) break of drives of regulating and isolating devices;

20) partial (complete) actuation (failure of actuation) of the safety system in various operation modes.

5.4.5. Operation modes with loss the primary circuit coolant:

1) actuation and failure of the primary circuit relief devices to close;

2) break of coolant pipelines of the primary circuit from small to maximum possible diameter specified in the design.

In the scope of modeling there shall be included all described in the design locations of the coolant leak: inside or beyond the leaktight compartments; at cut-off or unisolated parts of the pipelines; in adjacent systems (for example, system of component cooling of the reactor facility equipment, the secondary circuit – for multi-circuit NPP, etc.);

3) break of technological channel (for RBMK type of reactors).

5.4.6. Operation modes with breaks of steam pipelines and feedwater pipelines from small to maximum possible diameter specified in the design.

In the scope of modeling there shall be included all described in the design locations of the coolant leak: inside or beyond the leaktight compartments; at cut-off or unisolated parts of the pipelines; in adjacent systems.

5.4.7. Operation modes with malfunctions during process of fuel assemblies reloading (for RBMK type of reactors).

5.4.8. Operation modes with leaks, that can be compensated, of radioactive agents from systems and equipment.

5.4.9. Operation modes with loss electrical power sources:

1) partial loss of power to the unit;

2) total loss of power to the unit.

5.4.10. Fire:

1) fire in the power-unit control room;

2) fire in the turbine hall;

3) fire in compartments where the safety systems are located;

4) fire in cable tunnels.

6. REQUIREMENTS TO THE MATHEMATICAL AND SOFTWARE MEANS OF THE FULL-SCOPE SIMULATOR

6.1. Requirements to the scope and limits of simulation

6.1.1. The scope of simulation of the technological systems and equipment for all simulated modes of operation shall be such that the trainees are required to take the same actions and procedures on the FSS as on the reference power-unit.

6.1.2. In the scope of mathematical modeling there shall be included technological systems, monitoring and control systems enabling functioning of the power-unit in all operation modes specified in Section 5. Level of working out of simulation in detail shall be such that simulation of functioning of the power-unit in simulated modes of operation is identical to the real processes.

6.1.3. The scope of simulation of the power-unit systems is defined by list of monitored from the UCR parameters (being measured or calculated), by the power-unit operation modes and list simulated malfunctions in normal operation.

It is mandatory to simulate on the FSS all safety related systems, monitored and controlled from the UCR, as well systems having impact on the reactor transients processes.

6.1.4. All calculated parameters, displayed for operators of the UCR and being calculated in information-computing subsystems of the Automated System of Control of the Technological Process (the information-computing system, the reactor control instrumentation system, the automated system of the turbine control, etc.) , shall be presented in the FSS.

The list of calculated parameters shall be substantiated in the FSS design.

6.1.5. Simulated on the FSS systems, having NPP safety significance, shall correspond to the reference power-unit with regard to characteristics and number of equipment units.

6.1.6. On the FSS there shall be simulated all auxiliary systems and equipment necessary for realization of operation modes, described in Section 5, monitoring and control of which is conducted from the non-operative panels of the UCR, Central Control Room, Local Control Room or «locally». Information on their conditions shall be displayed on the Instructor Station.

6.1.7. The FSS shall support the conduct, by operator, of evolutions (performed from the UCR) necessary for pre-start preparation of systems significant to safety of the power-unit. These evolutions shall also include tests of availability of protection systems, alarm signal system, interlocks and other actions necessary for run-up, checking, and operational testing of systems and equipment having safety significance.

6.1.8. The limits of simulation shall overlap the design limits of the reference power-unit and afford simulation of functioning of the emergency protection and the protection safety systems in all operation modes specified in Section 5.

The specific values of the limits of simulation shall be defined in the FSS design.

6.1.9. In order to avoid negative consequences the FSS shall feature monitoring and warning means for notification of the instructor that parameters of the simulated process exceeded the values that are beyond the limits of the mathematical model functioning or beyond limits of the NPP power-unit operation modes.

6.2. Requirements to the mathematical models of the full-scope simulator

6.2.1. The FSS mathematical models shall describe the dynamic processes in such way that changes of technological parameters in simulated operation modes are in conformity with the corresponding parameters of the real operation modes or with calculated data, and the physical laws of nature. are not violated.

6.2.2. The simulation of the power-unit operation shall be in real time (as the main functioning mode). There shall be also included other simulation capabilities such as freezing of the simulation process, changing of time scale of the simulation (fast time, slow time).

The changing of time scale of the simulation is applicable only to certain predeterminated processes such as heating-up of equipment during start-up, cooling-down, xenon oscillations, etc.

6.2.3. All technological processes shall be simulated until stable technological parameters are obtained or until the limits of the simulation are reached. In this case the process of simulation is deemed to be terminated.

6.2.4. Time lag of the actuators movement after sending of commands from controls on the panels of he UCR shall be the same as on the reference power-unit.

6.2.5. The time of displaying of frames on demand as well as the time of updating of dynamic parameters on the displays of operators of the UCR shall be the same as on the reference power-unit.

6.2.6. The sequence and duration of performing by operators on the FSS of operation procedures (for example, while conducting switching-over of equipment "locally" in response to the commands of the UCR operator) shall correspond to the procedure and normal duration of such actions on the reference power-unit*.

6.2.7. The FSS mathematical model shall be verified. For the verification shall be used experimental data from the reference power-unit or analogous NPP power-units, results of testing of the power-unit during start-up and adjustment work period, physical and power start-ups, reports on results of investigations of mulfunctions in NPP power-units operation which occurred

* L*engthily technological evolutions, that are not necessary for training purposes, may be simulated in fast time mode.*

on the power-units of the same types during operation period, design data on calculation transients and abnormal operation of the main equipment and the power-unit in the whole, as well results of calculation on the basis of more detailed programmes and programme complexes.

6.2.8. The FSS verification procedure shall be performed pursuant to Programme of FSS verification, established by the operating organization . The results of the FSS mathematical model verification shall be stated in the special report.

6.2.9. The verification report has to comprise principal data on verification of computing codes used in the mathematical model, analysis of the mathematical model, results of tests and list of experimental and calculated operation modes of the power-unit, comparison of processes simulated on the FSS against experimental and design data, analysis of compliance with this normative document.

6.3. Requirements to the accuracy of the modeling

6.3.1. General requirements to the accuracy

6.3.1.1. Errors of instruments on the panels of the simulated UCR shall not exceed errors of corresponding instruments of the reference power-unit.

6.3.1.2. There shall be fulfilled the requirement concerning the reproduction of a simulated process.

When the FSS is repeatedly started up from the same initial conditions and the same combination of automatic actions is used the changes of simulated analogous and discrete parameters shall be every time identical within allowed errors.

6.3.2. Requirements to accuracy of simulation of power-unit parameters in stationary state operation modes.

6.3.2.1. Verification of the accuracy of computing of the power-unit parameters in stationary state operation modes shall be performed at least at four different power levels, covering all power range of load, beginning from turning on of the turbine facility (for example, 25, 50, 75, 100%).

The !00% rated power level is mandatory for testing; values of intermediate power levels may be chosen with deviations from the aforementioned values taking into account availability of estimated and actual data on the reference power-unit.

6.3.2.2. Initial conditions necessary for verification of the parameters shall be defined through executing of operational procedures of start-up and increasing of the reference power-unit load.

6.3.2.3. Calculated on the FSS parameters of a technological process shall be identical to the parameters of the reference power-unit in the following range of tolerance values (not taking into account errors of measuring devices of the reference power-unit:

1) list of parameters with tolerance +/-1% of measuring channel range :
   a) for VVER type reactors:
- coolant temperature in "cold leg" of the loops;
- coolant temperature in "hot leg" of the loops;
- average temperature of the primary coolant;
- steam pressure in the steam generator;
- pressure in the main steam header;
- primary circuit

b) for RBMF type reactors
- drum-type steam separator pressure;
- pressure in the main steam header;
- total coolant flow in the multiple forced circuit;

2) list of parameters with tolerance +/-2% of measuring channel range :
   a) for VVER type reactors:

- unit power (electrical);
- unit power (thermal);
- neutron flux (%);
- total core flow;
- core differential pressure;
- steam generator feedwater flow;
- feedwater temperature at steam generator inlet;
- primary circuit makeup flow;
- primary circuit blow-down flow;
- main condensate flow to deaerator;
- temperature of the main condensate at the deaerator inlet;
- pressure in feedwater deaerators;

b) for RBMF type reactors

- unit power (electrical);
- unit power (thermal);
- neutron flux (%);
- steam flow from steam generator;
- drum-type steam separator feedwater flow;
- feedwater temperature;
- main condensate flow after low temperature heater;
- temperature of the main condensate at the deaerator inlet;
- pressure in feedwater deaerators;

3) for parameters not being listed in i.i.1) and 2) the tolerance is +/-10% of measuring channel range :

6.3.2.4. Requirements to stability of stationary state simulation:

a) calculated on the FSS current values of parameters of the power-unit stationary state mode, listed in i.i.6.3.2.3 1) and 2) shall not differ by more than +-1% or +-2%, as appropriate, of their initial values during 60 minutes period of operation.
b) verification of stability of stationary state simulation shall be performed at least at three unit power levels, including 100% of rated power.

6.3.2.5. Requirements to accuracy of simulation during performing of procedures of the power-unit normal operation modes.

For evaluation of accuracy of simulation on the FSS of normal operation modes shall be used following criteria:

1) when performing on the FSS the procedures related to programmes of commissioning and pre-operational adjustments, power start-up and bringing the power-unit to the design rated power there shall be satisfied the acceptance criteria included in the said programmes;
2) when performing on the FSS the procedures related to programmes of dynamical testing of systems and equipment of the power-unit there shall be satisfied the acceptance criteria included in the said programmes;
3) when performing on the FSS the programmes of start-up and shutdown procedures as well pre-planned tests there shall be satisfied the acceptance criteria included in the said programmes;
4) observable change of parameters on devices on panels of the FSS during performing procedures of the normal operation shall correspond in respect to direction and trend to the change in parameters on the reference power-unit in identical conditions;
5) if during performing procedures of the normal operation on the reference power-unit there takes place of actuation of alarms or automatic actions then, in identical conditions, these events shall occur on the FSS too;

6) on the FSS there shall not take place actuation of alarms or automatic actions if, in identical conditions, these events do not occur on the reference power-unit.

6.3.4. Requirements to accuracy of simulation of abnormal operation of the power-unit.

For evaluation of accuracy of simulation on the FSS of transients during abnormal operation modes (i.5.4) shall be used following criteria:

1) observable change of parameters on devices on panels of the FSS in respect to direction and trend shall correspond to those taken as data base on basis of expert evaluation of experimental, design or calculated data;
2) if on the reference power-unit there takes place of actuation of alarms or automatic actions then in, identical conditions, these events shall occur on the FSS;
3) on the FSS there shall not take place actuation of alarms or automatic actions if in identical conditions these events do not occur on the reference power-unit.

6.4. Requirements to the software

6.4.1. The software shall ensure possibility of correction of parameters of the main technological equipment and systems, changing of setpoints of protection actuations, interlocks, alarms, regulator settings.

6.4.2. The software shall provide the capability for convenient insertion and termination of simulated malfunctions (abnormal events in the power-unit operation) as isolated as well as multiple ones in any combination and in any time sequence within the limits of specified scope of simulation of the power-unit.

6.4.3. For description of the FSS mathematical model it is desirable to use programming languages of the high lelel.

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