

## Abstracts

Journal "Problems of Nuclear Science and Engineering. Series: Physics of Nuclear Reactors"  
issue No.3, 2015

Prepared by EDO GIDROPRESS

UDC 621.039.58

### **Application of Artificial Neural Networks for Scram Reliability Analyses**

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The reactor scram reliability in case of multiple control rods failures has been studied. There is a great number of combinations of control rod failures. It is impossible to perform thermo-hydraulic calculational verification even for a small part of these possible combinations. The procedure using artificial neural networks, which can estimate probability of safety criteria violations for different combinations of failures, has been developed.

*Key Words:* Artificial Neural Network, Uncertainty Analysis, VVER, Reactor, Reliability, Scram System, Steam Line Rupture.

UDC 621.039.58

### **Analysis of Effects of Possible Combinations of Stuck CPS Control Rods on Reliability of VVER Reactor Trip System Function**

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The paper presents typical problems of reactor trip system reliability analysis for PSA, i.e. reduction in reliability model calculation conservatism and consideration of common-cause failures for a wide range of single-type components. A study covers effect of a number of CPS control rods stuck and their combinations on recriticality temperature. The principle of consideration of only "hazardous" sticking combinations of control rods has been introduced in reliability analyses by the results of study that enables to obtain realistic reliability parameters for the reactor trip system.

*Key Words:* probabilistic safety assessment, reliability analysis, VVER, reactor trip system, control rods, sticking, theory of combinations.

UDC 621.039.58

### **Conceptual Issues on Creation of VVER RP Safety Parameter Display System**

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According to the concept of defense-in-depth, technical and organizational measures on protection of physical barriers on the way of propagation of ionizing radiation and radioactive substances into the environment shall be provided with all 5-levels of defense-in-depth. Safety parameter display system (SPDS), being a part of supporting system of NPP operational personnel is used at decision-making for power unit control with the 1-st

– 4-th levels of defense-in-depth. For SPDS the following definition of safety parameters (SP) is offered: SP are RP and NPP parameters under control characterizing the state of safety functions and efficiency of their fulfillment as to maintenance of integrity of physical barriers. Interrelation between SP and safety functions, operational procedures and accident management procedures is considered. The ways of choice of SP and establishment of relation of these parameters with limits of safe operation, design limits and safety criteria are analyzed. Efficiency of SP application is analyzed during elaboration of event-and symptom- oriented instructions on accident management and also during RP and NPP normal operation and anticipated operational occurrences.

*Key Words:* Safety Functions, Supporting System of Operational Personnel, Defense-in-Depth, Safety Parameters, VVER RP\_

UDC 621.039.58

## **TRAP-KS Code Package Three-Dimensional Neutron Kinetics Model Verification by Calculation Results of Benchmarks with Reactivity Variations**

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This work is implemented within the frames of code package TRAP-KS verification. Two benchmarks are analyzed. The first of them considers asymmetric control rod ejection at power operation. This process is characterized by fast reactivity insertion leading to short-term local power surge in the reactor. The second benchmark covers the experiment with xenon oscillations. Small negative reactivity insertion leading to power decrease is initiated. This process results in space oscillations of xenon concentration. Some time later these oscillations are suppressed by control group under external control.

*Key Words:* verification, TRAP-KS Code Package, Reactivity-Initiated Accidents, CPS Control Rod Ejection, Space Xenon Oscillations, Steam Line Rupture.

UDC 621.039.58

## **Conservative Methods for Determination of Time of Initial Event Occurrence at Maneuvering Power Modes for Calculation of Accident Processes at VVER RP as per Code Package KORSAR/GP**

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One of the specific features of maneuvering power modes is transient xenon concentration variation in the core. Thus carrying out calculations of accidents, the problem arises on determination of the most unfavourable time moment of initiating event occurrence. The methods are proposed on the basis of canonical decomposition of acceptance criteria parameters. The decomposition basis is vector with regulation parameters in its components. As a result there are criteria parameters as functions of regulation parameters. The result of this procedure is time point for conservative initial event time appearance. Such methods are oriented to the coupled calculations during probabilistic safety analysis development.

*Key Words:* Cyclic Load Curve Operation, Power, Reactivity Emergency Process, Space Xenon Oscillations, Main Steam Header Break, Canonical Decomposition, Criteria Parameters, PSA.

UDC .001.2

## **Generalization of Two-Dimensional DDL-Schemes of GQ-Method for Threedimensional Arbitrary Hexahedral Spatial Mesh**

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The DDL-schemes of GQ3D-method for approximation of DS<sub>n</sub> transport equation in 3D Cartesian geometry for unstructured hexahedral mesh is developed and tested.

*Key Words:* DDL-Schemes, DS<sub>n</sub> Transport Equation, Reactor, 3D Unstructured Mesh.

UDC .004.5

## **Verification of Program PMSNSYS by Methodical Tests T. Takeda**

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Verification results of DDL-schemes of GQ-method are presented. The given schemes are realized in program PMSNSYS. Verification was performed by benchmarks collection of T. Takeda.

*Key Words:* PMSNSYS, Verification, Effective Neutron Multiplication Factor, Groupwise Fluxes, Benchmark, T. Takeda, DDL-Schemes.

UDC 621.039.542

## **Justification of Introduction of the Modernized Fuel at "PAKS" NPP**

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The paper describes a procedure for transfer the Paks NPP Unit reactors to operation with the modernized fuel assemblies with U-Gd fuel in a new 4 year fuel cycle. A specific figure of the economic effect achieved due to introduction of the new fuel component is given in view of the scheduled length of operation of all four NPP Units. The enterprises participating in the work under the contract are listed with description of their specific contribution to the total scope of the justification documentation. The paper also covers the list and format of the design criteria formalization that require a revision and new justification of the modernized fuel due to its introduction at the Paks NPP Units. The list of the basic regulatory and engineering documentation is provided that is valid both in the Russian Federation and in Hungary and makes the basis for justification of the change of RP design materials.

*Key Words:* "Paks" NPP; U-Gd Fuel; Fuel Cycle; Design Requirements; Design Criteria; Core; Fuel Assembly; Fuel Burn-up.

UDC 621.039.546

## **Experimental Studies of Vibration and Fretting-Wear of FA-KVADRAT Fuel**

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The paper covers the results of the studies to justify vibration strength of the Russian design of FA-K fuel assembly for PWR-900 reactor (FA-KVADRAT). The program of the studies consisted of two stages:

- study of fuel rod flow-induced vibration in a full-scale FA dummy at coolant thermal-hydraulic parameters that are close to the parameters of normal operation of PWR reactor;
- determination of the limiting parameters of fuel rod vibration by the results of long-term tests of the fuel rods of FA-K fuel assembly with the power applied to induce the transverse vibration under the conditions of water chemistry of PWR.

By the results of the first stage of the tests of a full-scale FA-K dummy the levels of fuel rod vibration were determined at coolant thermal-hydraulic parameters close to those standard for PWR reactor, the effect of the structural and process factors on the vibration level was determined.

At the second stage of the fuel rod dummy tests for fretting-wear the effect of the amplitude was determined as well as frequency of fuel rod vibration and the value of the cladding-to-spacer grid cell gap on the depth of fuel rod cladding wear under standard coolant parameters, the estimation was made of the threshold values of the vibration-induced motion of the middle of the span that being exceeded can lead to the development of inadmissible cladding fretting-wear.

*Key Words:* Fretting-Wear, Vibration, Fuel Rods, FA, FA-K, Wear-Free Area Boundary.

UDC 621.039

## **Dynamic Analysis of Fuel Handling Equipment Deformation at Design Basis Accidents**

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The present article contains methodology and some numerical results of dynamic analysis of deformation of fuel handling equipment at design basis accidents pertained to dropping heavy objects. A number of accidents with nuclear fuel handling equipment were analyzed using 3D modeling technique by means of ANSYS LS-DYNA software. The developed approach can be applied to calculate final and intermediate fuel configurations during the accident, which are the essential data for the nuclear fuel handling equipment safety analysis.

*Key Words:* Drop of Heavy Objects, Fuel Assembly, Fuel Handling Equipment.

UDC 004.42, 004.94

## **Analysis of Probability of VVER Reactor Vessel Destruction Using Effective Calculation Model**

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The article represents the description of probabilistic model of VVER RP reactor vessel destruction, constructed on the basis of the physical-and-mechanical model including processes of sub-critical and critical crack growth. For modeling random processes Monte Carlo method is used. For realization of simulating process spe-

cial software and the calculated algorithms were developed. They enable to reduce essentially computational time and provide possibility of control of the assigned error. The tests estimating efficiency of the developed algorithms are given.

*Key Words:* Effective Computational Model, Model of the Reactor Vessel Destruction, Effective Algorithms, Construction of Computational Experiment, Analysis Facilities of the Results.