Approved by   
Order of the Federal Environmental, Industrial and Nuclear Supervision Service   
dated April 24, 2012 No. 264

PROVISION   
ON THE RECOMMENDATIONS FOR COMPARING THE CALCULATED AND MEASURED REACTIVITY ON NUCLEAR SAFETY ASSESSMENT OF REACTOR FACILITIES WITH VVER

(RB-074-12)

I. General

1. The provision on the recommendations for comparing the calculated and measured reactivity on nuclear safety assessment of reactor facilities with VVER (hereinafter the Provision) is amongst the safety guides, serves as guidelines and is no regulatory legal act.

2. This Provision contains the recommendations of the Federal Environmental, Industrial and Nuclear Supervision Service for comparing the calculated and measured reactivity on nuclear safety assessment of the reactor facilities with VVER.

3. This Provision contains recommendations for:

comparing the calculated and measured reactivity and values determined with its help, primarily efficiency of emergency protection;

the required design possibilities and application of software (hereinafter SW) for design simulation of reactivity;

SW verification and examination (validation) for design simulation of the reactivity measurements;

determining calculation error of the efficiency of emergency protection based on comparison of the measured and calculated reactivity;

obtaining other safety-related parameters which are determined based on the measured reactivity, and comparison of these parameters with the calculated values.

4. The values which are design and operation limits, for example efficiency of the control elements and emergency protection, rate of reactivity insertion, effects and reactivity factors are related to the "reactivity" concept. Their values are justified in the reactor plant design (hereinafter RP), and some of them are confirmed in the operation process at the operating RP by measurements.

5. The recommendations which are applicable for the following are presented in this Provision:

comparison of the measured reactivity with the values obtained using the SW of stationary calculation and design simulation of measurements for non-stationary models for the reactor operation modes wherein the power changes by several orders in a short span of time (for example, when measuring the efficiency of emergency protection, and during the measurements in the sub-critical state and measurements in the process thereof the operation of RP systems and equipment is considered);

comparison of measured effects and reactivity factors with obtained from stationary SW and SW used for design simulation of measurement using different models of the RP systems and equipment impacting the reactivity value;

SW validation.

6. The terms and definitions used in this Provision including the reactivity concept, which is not defined in the Federal rules and regulations in force in the field of atomic energy use have been given in the Appendix and is recommended for use when comparing the calculated and design reactivity on nuclear safety assessment of RP with VVER.

7. In this Provision the source of neutrons not including the instantaneous and delayed fission neutrons is understood under the distributed source of neutrons during measurements in sub-critical state.

II. Recommendations for calculation of reactivity, design-basis simulation of reactivity measurement of VVER reactors and recommendations for relevant software

8. The reactivity calculation is recommended to perform for validated SW-imitators of reactor core operation. In the appendix to the SW validation datasheet in the sub-item "Tolerance provided in the range of permitted values of the parameters" given in appendix No. 2 to the Instruction on organizing performance of examination of the software used on safety assessment and/or assurance of the nuclear facilities approved by the Order of the Federal Environmental, Industrial and Nuclear Supervision Service dated August 19, 2008 No. 634 (hereinafter SW validation datasheet), it is recommended to specify the calculation error of effective neutron multiplication factor and power distribution corresponding to it in the reactor core.

9. During design-basis simulation of reactivity measurement it is recommended to:

use the SW of non-stationary distributed joint neutron-physical and thermo-hydraulic (hereinafter NP and TH) calculation of RP; moreover, in the design-basis simulation of RP it is recommended to include simulation of systems and equipment, the operation thereof impacts the reactivity measurement;

use the SW which contains the version (part) designed for stationary calculation of RP; moreover it is recommended to perform calculation so that the tolerance of the main parameters of the RP stationary state calculated using SW simulation of the reactivity measurements was not higher than the tolerance of the relevant parameters calculated according to SW-imitators of RP core operation used for the PR operation support;

include the design-basis model of the reactimeter in the SW;

implement the possibility of calculation of the neutron flux at the location of signal sensor processed by the reactimeter;

implement the possibility of calculation of the neutron source and calculation of the distribution of neutron flux from the source not related with the instantaneous and delayed fission neutrons;

perform design-basis simulation of the reactivity measurements for the validated SW; moreover it is recommended to specify the tolerances of the values in the appendix to the validation datasheet of such SW, the calculation thereof is stipulated in the item 17 of this Provision.

III. Submission and comparison of the calculated and measured reactivities

10. When submitting the results of reactivity calculation it is recommended to:

specify data on SW validation (based on which the reactivity calculation is performed) and information on the calculation procedure in the minimum required scope for comparison no less than in the item 3 "Information on the calculation procedures implemented in SW" and item 4 "Information on databases (evaluated nuclear data files) used in SW" of the appendix to the SW validation datasheet;

provide the following information on each specific reactivity calculation:

core fuel load pattern with detailed characteristic of the cassettes included in the load;

information on core initial (unperturbed) state;

information on inserted perturbance;

information on the core end state;

value of calculated reactivity.

11. When submitting the results of reactivity calculation it is recommended to:

give the measurement results according to the procedures approved by the operator;

give information on the constants of delayed neutrons used in the reactimeter or SW replacing it, and source of their receipt viz. evaluated nuclear data file, index of its version, considered isotopes, number of delayed neutron groups;

together with the values of reactivity measured by the reactimeter give the ionizing chamber currents and other parameters measured during the transition process individual for each of the detectors used;

give information on the applied processing procedure when performing statistical and/or any other primary processing of the ionizing chamber signal or reactimeter.

12. When submitting the results of design-basis simulation of reactivity measurement it is recommended to:

specify data on SW validation (based on which the design-basis simulation of reactivity measurement is performed) and information on the calculation procedure in the minimum required scope for comparison no less than in the item 3 "Information on the calculation procedures implemented in SW" and item 4 "Information on databases (evaluated nuclear data files) used in SW" of the appendix to the SW validation datasheet, besides in the sub-item 2.1 of this appendix "Purpose of SW" it is recommended to specify that the SW is designed for design-basis simulation of reactivity measurement'

specify the required characteristics of the stationary state of RP before simulation of reactivity measurement;

in the SW for design-basis simulation of reactivity measurement use the same few-group diffusion files (grid coefficient) which is used in SW for steady-state calculation of reactiivity;

give the list RP systems including the control and protection system (hereinafter CPS), in-core control system and complex of neutron flux monitoring equipment the operation thereof is considered during the design-basis simulation of the measurements of reactivity, and give information on adequacy and errors of simulation;

give the results and calculation error of neutron source, if it is accounted for;

give the reactivity measurement scenarios;

give the description and value of the parameters used in the design-basis model of the reactimeter;

give a description of the procedure and source data (including information on the nuclear data file), which were used for calculation of delayed neutron parameters in the non-steady state equations describing the diffusion of neutrons in the core.

give information on adaptation of the reactimeter model in the specific calculation, for example information on use of mutual standardization of experimental readings of the reactimeter and results obtained on its design-basis simulation;

give the following results of design-basis simulation of the reactivity measurement:

- change of RP parameters in the design-basis simulation process;

- reactivity value obtained using the design-basis model of the reactimeter;

- reactivity obtained following steady-state calculation;

- design change of the ionizing chamber current during the reactivity measurement simulation.

13. When comparing the calculated, measured and obtained following design-basis simulation of reactivity measurement it is recommended to:

specify the delayed neutron constants used in the reactimeter and SW simulated the reactimeter;

when comparing the calculated, measured and obtained following design-basis simulation of reactivity in the documents assessing safety of RP, including operational documents, give:

the results of comparison of measured reactivity and reactivity obtained using the design-basis simulation i.e. calculated according to the reactimeter model contained in the SW of design-basis simiulation of reactivity measurement;

results of comparison of calculated reactivity according to the steady-state SW-imitator of core operation and for steady-state part of reactivity measurement simulation SW;

tolerances of values about which is mentioned in the previous paragraphs of this item.

IV. Recommendations for determining the effectiveness of emergency protection based on the comparison of calculated, measured and obtained following design-basis simulation of the reactivity measurement.

14. According to the requirements of the Nuclear Safety Provisions (NP-082-07) approved by the ordinance of the Federal Environmental, Industrial and Nuclear Supervision Service No. 4 dated December 10, 2007. (registered by the Ministry of Justice of the Russian Federation dated January 21, 2008, registration number 10951; bulletin of regulations of the federal executive authorities No. 20, 2008), minimum efficiency of emergency protection is established sufficient for the transfer of RP at any time to sub-critical state from the core state with maximum criticality without breach of the design limits. Minimum efficiency of emergency protection is justified in the RP design and determined for the states at minimum controlled reactor power (hereinafter MCRP) and at rated power. According to the requirements of the operator's guidelines the efficiency of emergency protection of VVER type reactors is calculated before the start of operation of each fuel loading. Measurements for MCRP are performed for confirming the design value of emergency protection efficiency. The measurements and their processing are made according to the procedure stated in the operator's guidelines.

15. The design efficiency of emergency protection is recommended to determine by the absolute value as the difference between two revers effective multiplication factors calculated according to steady state calculation SW in two states viz. initial and end states. In the initial state all the CPS control rods (hereinafter CR) excluding the CR of control group are on the upper limit switch. In the end state all the CPS CR are in the lower limit switch, remaining parameters correspond to the first state. The value of reactivity measured according to the reactimeter following the displacement of all CPS CR to the lower limit switch is recommended to consider as the measured efficiency of emergency protection. In a similar manner it is recommended to determine the efficiency of emergency protection without one or several CPS CR.

16. The efficiency of emergency protection obtained following design-basis simulation of the measurement is recommended to consider as the change of reactivity calculated according to the reactimeter model contained in the SW used for design-basis simulation. The initial state during design-basis simulation of measurement of the efficiency of emergency protection is recommended to select in such manner that it coincided with the initial state defined in the item 15 of this Provision.

17. The emergency protection efficiency error obtained following the calculation considering the comparison of measured and calculated reactivity is recommended to give in the appendix to the SW validation datasheet for design-basis simulation of reactivity. If different SW is used for calculation of reactivity and simulation of reactivity measurements, the determination of error is recommended to give in the safety assessment documents of the RP next loading in which the comparison of measured and calculated values are located.

V. Recommendations for determining the effects and coefficients of reactivity, based on the comparison of calculated, measured and obtained following design simulation of the reactivity measurement.

18. The measurements and processing of measurements of the effects and coefficients of reactivity, effectiveness of individual CPS CR, groups of CPS CR, differential efficiency of CPS CR are recommended to perform according to the procedures approved by the operator.

19. The recommendations for determining the efficiency of CPS CR (or groups of CPS CR) determined through dropping from the critical state or dropping in sub-critical state (extra insertion), and errors of this value coincide with the recommendations of the chapter IV of this Provision, formulated for determining the efficiency of emergency protection.

20. The design simulation of the differential and integral efficiency of the groups of CPS on their compensation by boric acid and the effects and coefficients of reactivity for boric acid performed at minimum controllable power level is recommended to perform both for the stationary SW-RP operation simulators and for SW of non-stationary joint NP and TH calculation.

21. The design simulation of the measurements of the effects and coefficients of reactivity which consists in the compensation of induced insurges from any parameter due to CPS CR with an efficiency known in advance is recommended to perform according to the SW of the joint non-stationary NP and TH calculation. The efficiency of CPS CR may change in the disturbance compensation process. It is recommended to provide for the possibility of simulating the operation of required reactor facility systems in the SW designed for design simulation of the measurements, and in the appendix to the certification datasheet of SW in the sub-item 2.6 "Tolerance provided in the field of permitted values of parameters" it is recommended to include the tolerances of parameters impacting the measurement.

22. The tolerances of calculated values of the coefficients and effects of reactivity obtained from mock-up reactor-SW are recommended to determine considering the design simulation of the measurements.

Appendix   
to the Provision on recommendations for comparing the calculated and measured reactivity on nuclear safety assessment of the reactor facilities with VVER approved by Order of the Federal Environmental, Industrial and Nuclear Supervision Service   
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TERMS AND DEFINITIONS

Reactivity - measure of deviation of the neutron multiplication factor from 1.ро = 1/kef1 - 1/kef2,

where kef - effective multiplication factors of the initial and end states. The value po is also called the calculated reactivity.

The effective multiplication factor is determined from the resolution of the stationary task for SW-imitators of the RP core operation and represents the ratio of full generation of neutrons to the complete absorption and leakage.

Measured reactivity is the reactivity measured by the reactimeter (device unit) based on the signal on neutron flux (neutron flux power) from one or several in-core or ex-core sensors.

Reactivity obtained following design-basis simulation of measurement is the reactivity obtained following design-basis simulation of the reactimeter, the parameters thereof is recommended to select so that they coincided with the parameters of the reactimeter with the assistance thereof the measurements are performed. Besides the following conditions are recommended to be met. Distribution of the neutron flux (neutron flux power) in the core is calculated according to the SW of the joint non-steady state distribution full-scale NP and TH of RP calculation. The values of the neutron flux at the location of ex-core sensors of the reactimeter is recommended to calculate according to SW with known tolerance.

Reactimeter is a device (measurement unit) recording the change of neutron flux (neutron flux power) using the sensors located inside and outside the core and performing primary processing of signal for getting the measured reactivity under a law or algorithm known in advance. The measurement unit may include statistical processing of the primary results, record of background current of the sensors on receipt of the final value of reactivity.

Reactivity effect is the change of reactivity following the change of one of the parameters of RP, for example power, average temperatures of fuel and coolant, concentration of liquid poison (boric acid), xenon concentration. Besides the parameter change interval is specified, if necessary, the space distribution function.

Reactivity factor is the effect of reactivity related to the value of change of the relevant parameter, at that it is assumed that all other parameters remain constant.