UTILISATION OF SELF-POWERED NEUTRON DETECTORS FOR REACTIVITY CONTROL

V. Borissenko
Institute for Nuclear Research (Ukraine)

Abstract

This article presents the results of an investigation regarding the neutronic characteristics of core fuel loading in WWER-1000 reactors.

Specifically, issues regarding experimental coefficient reactivity tests occupy an extremely important position in reactor safety substantiation.

The results of the investigation concerning reactivity coefficient determination at the first power units with the WWER-1000 were difficult to interpret.

Methods are determined for the creation of a combined system of reactivity monitoring and the pilot-scale production of the INR of the Ukrainian Science Academy. The Ukrainian NPP applied these methods at their facility. A model is created for the software and apparatus complex which is tested on WWER-1000.

Introduction

Ionisation chambers placed outside the reactor vessel are the main sources of information for the standard control system of the neutron power of WWER-1000.

Thermoneutron and space effects significantly influence the accuracy of determining WWER-1000 power and reactivity.

Experimental results

Thermoneutron effect appears at the change of temperature and/or coolant pressure of the primary circuit.

This effect is shown in inadequate measurement of core power and reactivity by the ionisation chambers (see Figure 1).

During the power and reactivity change space effects appear when the neutron flux distribution in reactor core is changed. This change may be caused by shifting control rods, coolant temperature variation, etc. Space effects greatly influence the measurement of the control rods' efficiency and reactivity effects.

This happens because the value of reactivity calculated by the point model of the reactor greatly depends on the placement of the neutron detector connected to the reactivity meter. Therefore, the main problem is to determine the relation between the reactivity value calculated according to indications of the certain detector and general reactivity of reactor. In large reactors the space instability could be referred to as the main indication of safety.

Space-distributed control of reactivity could be the kind of control necessary for conservation of this dynamic indication in the permitted limits.

Reactivity control system used with the SPDs

One of the possible solutions for this problem would be to create a system of reactor reactivity determination based on signals of in-core rhodium self-powered detectors (SPD). For its realisation the problem of determination of reactivity of reactor with the distributed parameters was solved and real dynamic parameters of the rhodium SPD were determined. In order to use SPD in the system of reactivity determination it is necessary to work out the effective algorithm which transforms the DCD inertial signal into a signal proportional to the instantaneous value of neutron flux in the place of detector installation.

Processing of the experimental data from SPD obtained during studies carried out on WWER-1000 in its different working conditions showed that to obtain values:

α - instantaneous component of SPD current,

E_1, E_2 - parts of the delayed component,

it is necessary to carry out more accurate measurements.

For this purpose a research channel was created on a WWR-M reactor. It contains the following detectors:

- Diminutive fission chamber;
- Diminutive γ-chamber;
- 3 SPDs with rhodium emitter (ÄÏÇ -1 M);
- 3 γ-calorimeters (with sensitive Fe, Zr elements and back-ground).

Results of experiments were recorded on-line on the magnetic carrier and then were processed according to the special programs. In the course of investigations the measurement of signals was carried out under different reactor operating conditions. Emphasis was directed toward investigations of detector signals under dynamic operating conditions of the reactor when its power was changed.

In order to obtain accurate SPD values the following reactor operating conditions were used.

The emergency rods shedding was accrued after the long-time operation of the reactor at the steady-state power level. In this case it was possible to more accurately determine SPD parameters such as α, E_1 and E_2.

Analysis of results of SPD parameters calculations allows to conclude that SPD parameters values depend on the volume of charge which was going through SPD and on burn-up of the surrounding fuel. The quantity evaluation of this dependence can be obtained from a series of experiments on the WWR-M reactor. The obtained data were basic for the creation of analogue and digital computing devices, so-called correctors, which determine the dependence between DCD current and neutron flux density during the voluntary condition of its change.

The model of the combined system of reactivity control (COSCOR) was made. Works are being carried out for the creation of a full-scale COSCOR where data of both in-core and out-core detectors of the neutron flux are used.

Space effects of reactivity

Investigation of the space dependence of the defector signal placed in-core in case of local disturbance needs application of the definite type of disturbance in time. As this type of disturbance it is convenient to use the trapezoid in time control rods movement. It is possible to carry out measurements on power reactors as the reactor power change is insignificant – only several percentage, and the duration of change is 10-20 s. Due to the physical persistence of the rhodium SPD used in the in-core monitoring system the current change is very insignificant. To measure such a current with sufficient accuracy it is necessary to use the means of either percolation of detector high frequency current or correction of detector current.

Investigations of neutron flux redistribution and change of reactivity on core volume when reactivity disturbances were caused by control rods were carried out on the unified energy unit of WWER-1000 reactor. An additional measuring system was used which allowed to record signals from 100 measuring channels with a frequency of 10 Hz during 200 s. These 100 channels counted the following:

- Thirteen neutron measuring channels, where every channel has seven rhodium SPD distributed uniformly length-wise the channel and the emitter length is 25 c;
- Six ionisation chambers placed in three channels in pairs in upper and lower parts through the core altitude, channels are placed symmetrically round the core at an angle of 120°;
- One channel for the purpose of recording the movement of the control rods;
- Two signal testing channels;

A location scheme of the neutron flux detectors whose signals were recorded during the trapezoid disturbance is shown in Figure 2.

Conclusions

The calculated investigations on the three-dimensional dynamics of neutron flux density behaviour during the reactivity disturbance qualitatively confirm the space effects measured on WWER-1000 reactor. The quantitative comparison is possible during further calculations which would be carried out on a three-dimensional program with more accurate data and under better conditions for experimentation.

In this case it would be possible to evaluate and adjust the calculation program BIPR which is used at present during reactor operation.

Figure 1. Dynamics of changes of WWER-1000 reactor unit power during low electricity load shedding

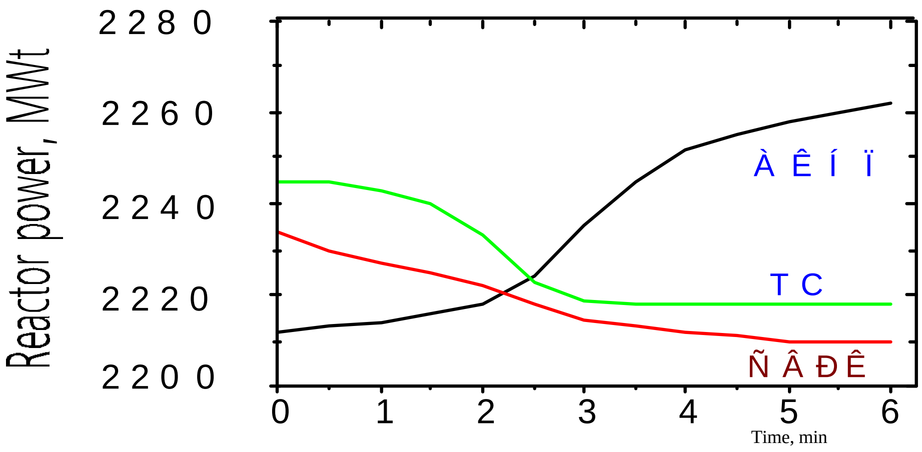

Figure 2. Location scheme of the neutron flux detectors (1-13) and control rods (CR)