достоверные и точные физико-математические модели.

2. Установлено, что наиболее точно изучаемый тепловой процесс характеризует стационарное распределение температуры в неоднородной, с точки зрения теплопроводности, среде.

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УДК 621.039

SAFETY ASSESSMENT OF THE IMPLEMENTATION OF ENHANCED-ALGORITHMS AT UKRAINIAN NPPS

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Стаття містить порівняльний аналітичний аналіз вдосконалених алгоритмів керування полем енерговиділення з алгоритмами, які використовувались раніше. Наведено результат розрахунку чотирирічної паливної кампанії, зроблений в коді БІПР-7А

Ключові слова: офсет, У-алгоритми, паливна кампанія

Статья содержит сравнительный аналитический анализ усовершенствованных алгоритмов управления неравномерностью поля энерговыделения с алгоритмами, используемыми ранее. Приведен результат расчета четырехлетней топливной кампании, сделанный в коде БИПР-7А

Ключевые слова: офсет, У-алгоритмы, топливная кампания

This article contains comparison of analytical analysis of Enhanced-algorithms to control power distribution in active zone with algorithm that was used before. The result of calculation of four-year fuel-campaign with using program code BIPR-7A is produced

Keywords: offset, E-algorithms, fuel campaign

1. Introduction

Nuclear power engineering of Ukraine's nuclear energetic is based on thermal neutron reactors. WWER-1000 (water-cooled and water-moderated energy reactor) is the most common type of the reactors in Ukraine.

The widespread development of nuclear energy comes out on top the problems of accident-free operation, high reliability of NPP equipment and high economic indices. Besides this Nuclear power plants in Ukraine generate more than 50% of all electricity production of the country. That's why the problem of necessity to use nuclear power plant for the Follow Load Operation (FLO) is very urgent. One of the solutions is to implement enhanced algorithms to control power distribution in active zones, which is now being introduced at Ukrainian nuclear power plants.

The introduction of the E-algorithm is implemented in order to improve safety and reliability of nuclear fuel during the transient at WWER-1000 (type B-320). Fuel rod assemblies for the four-year FC are operated in Ukrainian NPPs with reactors WWER-1000 at the moment. High scientific and technological importance is justification of safe service of FC in FLO mode. Criteria for safe service are the neutron-physical characteristics in the Ukrainian normative documents.

This draft paper contains a calculation of the efficiency of control rods and neutron-physical description of the active zone that loading fuel for the four-year FC with safety criteria in order to develop a methodology to calculate the five-year fuel company. In addition the calculation of four-year FC estimates the safe operation of fuel for a four-year FC, the conditions of safe operation, efficiency of control power and suppression of xenon oscillation.

2. Main advantages of the E-algorithm

Change power of reactor causes the transient process of xenon oscillation with a change in the total number of nuclei of 135Xe in the core and the corresponding change of reactivity.

The main disadvantages of the control algorithms that were used in WWER-1000 are:

Control rods (CRs) move in core up and down in the standard sequence in numerical order with the transmission of motion by 20% and 80% of the height of the core. As a result, automatic dipping groups after signal from enhanced alarm system can form non-optimal form of energy field with a maximum in the upper half of the core. Group 5 control offset, but when it go inside to the core it can cause significant radial deformation of the energy field, because its CRs are located close to the centre of the core, where is group 10. Operating experience, design research, and testing of the reactor in Zaporizhzhya NPP showed that algorithm need to modernize the location and methods of using control groups of the CPS CR (control rods of control and protection system).

Procedural restrictions on the distribution of energy in the reactor core inadequately defined that in some cases may impede the adoption of best management decisions of control offset.

Information support of operator does not comply with the current level of development of computer technology and software visualization process. In particular, it is not possible to predict the optimum operating regime of the reactor with a time-dependent distribution of xenon with the change of power.

A description of control algorithms in a technical documentation contains general guidance and it does not determine the current state of a non-stationary distribution of xenon.

Features of E-algorithms are a new approach to application of CPS CR, as well as the application of modern methods of information support of the operator. They include:

1. Three groups of control rods (10, 9, and 8) are used to control the reactor in normal operating time (Fig. 1). Group 10 resides in the core all the time, groups 9 and 8 can be put down into the core during both unloading of the reactor (only by using control groups the reactor can be discharged to the level of the own needs without changing the concentration of boric acid in the coolant) and suppression of xenon oscillations.

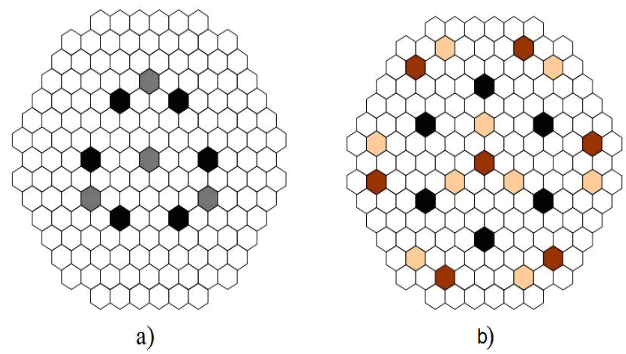

Fig. 1. Location of control groups of control rods for old algorithm (a) and enhanced algorithms to control power distribution in active zone (b)

2. A new position of group 10 purveys more sustainable balance of the radial distribution of power between centre and periphery of the active zone.

The translation of group motion is changed, when control rods run in or out from core that allows increasing safety. Composition and location of control group's CRs ensures effective control of power and altitudinal power distribution in active zone with minimal deformation of the radial distribution.

The new method of using control rods is applied to control offset without additional water exchange. Operator excites increase or decrease in the distance between the control groups that increases or decreases offset. Therefore operator can use the combined impact.

3. Dependence of the limiting value of the local power energy on the full reactor power eliminates the possibility of reducing energy production. Limit of axial offset is specified for all levels of the reactor power.

4. Module of information support of the operator is introduced to SVRK software (core control system), which gives information on the current condition of the reactor and the possibility to predict reactor behavior. Module of information support with advanced graphical visualization tools provides the operator the information on the reactor's state in visual and readable form.

5. The algorithms of preset offset maintenance, equilibrium offset maintenance, change of oscillation phase,

and the spatial localization of xenon processes are used to prevent and suppress xenon oscillations.

3. Experimental results

3.1 Input data and description of the programs used for calculations

This paper contains the results of the calculation of neutron-physical characteristics of the FC of unit 3 of Rivne NPP. Calculations were made on the basis of program code BIPR-7A, which uses mathematic model of reactor WWER-1000. Calculations of the three-dimensional power distribution, coefficients of irregularity dimensions, and transients were made by using program code PERMAK-A.

Programs BIPR-7A and PERMAK-A are a part of the graphical environment CASCADE, which also includes programs PROROK and PIR. PROROK allows choosing the FC. PIR is a program for simulation calculation of SVRK.

The program BIPR-7A is designed to calculate three-dimensional neutron kinetics in the active zone of water-moderated reactors and to operate in the software systems used in calculations, transient and emergency regimes of nuclear reactors, accompanied by substantial deformation of energy fields.

3.2 Results of modelling

Efficiency of control groups (10, 9, and 8) of CPS CR operating at the nominal parameters should not be less than 0.69% and not more than 1.04%, and in MCL (minimal control level) is not more than 0.97%.

Table 1 shows efficiency of control groups at the beginning of the campaign in MCL and in normal parameters. Table 2 shows values of the efficiency of group EAS (Enhanced Alarm System) of CPS CR and the power, which the reactor unload when input group of EAS in the AZ (active zone).

Table 1

Integral parameters 1 to 10 groups of AZ at the beginning of the campaign.

Power N,%	Integral efficiency,%									
	1	2	3	4	5	6	7	8	9	10
0	0.25	0.72	0.71	0.73	0.73	0.64	0.66	0.87	0.78	0.81
100	0.32	0.78	0.78	0.80	0.80	0.74	0.76	1.00	0.69	0.86

Table 2

Values of the efficiency of group EAS (enhanced alarm system) of CPS CR and the power, which the reactor unload when input group of EAS in the AZ.

Parameters, %	Beginning of the campaign	End of "boric" campaign
ρ	0.77	0.76
N	57	69

Fig. 2 shows a graph of power reduction in serial input CPS CR into the core for the two moments of the campaign. The movement begins with the group number 10 (H_{10} = 90%).

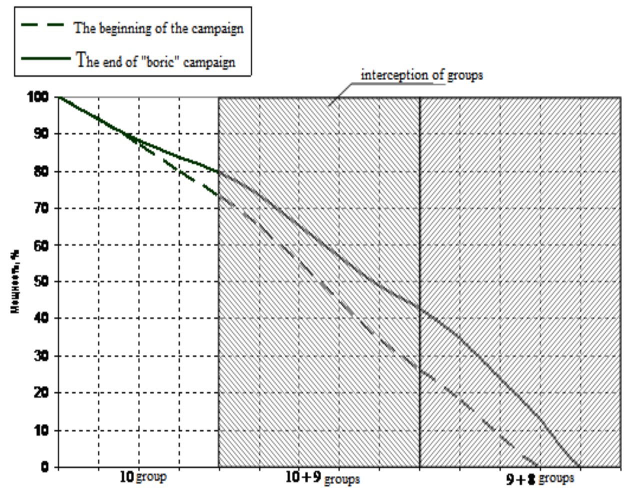

Fig. 2. Plot of power reduction in serial input CPS CR into the core for the two moments of the campaign.

Due to the plots and tables there is an opportunity to evaluate the effectiveness of control rods at work with use of E-algorithms for four-year fuel FC, efficiency of control power, and suppress of xenon oscillation in operating during the two most problematic moments of the campaign: on the power effect of reactivity and at the beginning of the campaign.

4. Conclusions

Based on the above calculation can be argued that E-algorithm permits to control neutron distribution in active zone more "gently" that in its turn does not lead to significant strain in the fuel cladding. E-algorithm fully satisfies the conditions of safe operation, effectively controls power, and suppresses xenon oscillation, as well as operating on the power effect of reactivity, with minimal water exchange. It reduces quantity of boric acid and amount of nuclear wastes. From the above it follows that E-algorithm decreases the amount of nuclear waste, thus increasing efficiency and safety. As you can see, E-algorithms have significant advantages and prospects compared with standard algorithms that were used previously.

However, one of the main advantages is the opportunity to use E-algorithm in FLO mode operations. At the moment in Ukrainian's NPPs reactors WWER-1000 operating with fuel rod assemblies for the four-year FC can operate with five-year FC, because this fuel can sustain change of power in the range of 75-100-75%.

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УДК 536.24:533.6.011

ТЕПЛОАЕРОДИНАМІЧНА ЕФЕКТИВНІСТЬ ПАКЕТІВ ТРУБ З ПОПЕРЕЧНИМИ РЕБРАМИ

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Виконана порівняльна оцінка теплоаеродинамічної ефективності шахових пакетів труб з поперечним оребренням. На прикладі варіантних теплових і аеродинамічних розрахунків теплообмінного пристрою показані переваги і недоліки кожного з розглянутих типів оребрених труб

Ключові слова: труба, ребро, пакет, теплообмін, аеродинаміка, ефективність, порівняння

Выполнена сравнительная оценка теплоаэродинамической эффективности шахматных пакетов труб с поперечным оребрением. На примере вариантных тепловых и аэродинамических расчетов теплообменного устройства показаны преимущества и недостатки каждого из рассмотренных типов оребренных труб

Ключевые слова: труба, ребро, пакет, теплообмен, аэродинамика, эффективность, сравнение

Comparative evaluation of the effectiveness of heat aerodynamic efficiency of staggered bundles of tubes with a cross-ribbing is performed. In the case of variation of thermal and aerodynamic calculations of heat exchange device shows the advantages and disadvantages of each of the above types of finned tubes

Keywords: tube, rib, bundle, heat transfer, aerodynamics, efficiency, comparison

a – ширина газоходу; b – висота газоходу; H – площа поверхні; k – коефіцієнт теплопередавання; L – довжина труб; M – маса труб; q – щільність теплового потоку; S – крок труб; t – температура; W – швидкість; ΔP – втрати тиску; ι – коефіцієнт оребрення; Π – компактність пакета.

Нижні індекси: l – довжина; пр – приведений; р – ребро; 1пм – один погонний метр; 0 – на один поперечний ряд; 1 – поперечний; 2 – поздовжній.

Загальні положення

Оцінка і порівняння ефективності оребрених поверхонь є досить складним завданням, насамперед, через необхідність враховування великої кількості зв'язаних між собою показників, що характеризують економічну роботу теплообмінного апарату. До таких показників можна віднести: коефіцієнт тепловіддачі і теплопередавання, аеродинамічний опір, компактність, довжину труб, масу, габарити, вартість теплообмінної секції і т.п.