4.3 PREPARATION OF PHYSICS COMMISSIONING FOR MOCHOVCE UNITS 3&4

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ABSTRACT

The Project "Mochovce Units 3&4 Completion" started in 2009 and it will be finished in 2013. VUJE, Inc. is one of the five main Project contractors for the Nuclear Island and it is responsible, inter alia, for Mochovce Units 3&4 commissioning. The commissioning of Units 3&4 includes the stages of Physics Commissioning and Power Commissioning. This paper deals with the preparation of Mochovce Units 3&4 Physics Commissioning. In the paper there is presented a preparation of some commissioning documents, e.g. "Quality Assurance Programme", "Commissioning Programme", "Stage Programme for Physics Commissioning", "Test working programmes", "Neutron-physics characteristics for Physics and Power Commissioning", etc. The scope of Physics Commissioning is presented by list of tests. For assessment of tests results so-called three-level acceptance criteria will be applied: realization, design and safety criteria. In the paper there are also presented computer codes, which will be used for neutron-physics characteristics calculation and the fuel loading scheme for the reactor core of Mochovce Unit 3.

1. INTRODUCTION

The Mochovce NPP with Units 3&4, named as "Mochovce 3&4" during its construction, is one of the three NPPs currently under construction in the European Union. The construction of Mochovce 3&4 started in 1986, but it was halted in 1992 because of lack of founds. At that time the construction reached approximately 30% completion in terms of mechanical equipment and 70% completion in terms of civil structures. Maintenance, preservation and protective activities on equipment and civil structures were carried out after the halt of the Mochovce 3&4 construction. In February 2007 the Slovak government (34% owner of Slovenske elektrarne, Inc.) and the ENEL (66% owner of Slovenske elektrarne, Inc.) representatives officially announced their intention to complete the "Mochovce 3&4" construction.
Note: Slovenske elektrarne, Inc. is the operator of Bohunice Units 3&4, Mochovce Units 1&2, two thermal power plants and 34 hydroelectric power plants [7].

The Project "Mochovce 3&4 Completion" was launched in 2009 and it will be finished in 2013. VUJE, Inc. is one of the five main project contractors for the Nuclear Island and it is responsible, inter alia, for the Mochovce 3&4 commissioning. This paper deals with the preparation of "Mochovce 3&4" physics commissioning. In the paper there are introduced basic commissioning documents like "Quality Assurance Programme", "Commissioning Programme", "Stage Programmes for Physics Commissioning" and "Test Working Programmes". Further in the paper there are also presented the scope of Physics Commissioning, acceptance criteria, the fuel loading scheme for the reactor core of Mochovce Unit 3 and computer codes, which will be used for neutron-physics characteristics calculation.

2. MOCHOVCE 3&4 COMMISSIONING STAGES

In accordance with Slovak legislation [1] the commissioning of Mochovce 3&4 is split into two stages: Physics Commissioning Stage and Power Commissioning Stage.

2.1 Physics Commissioning Stage

The purpose of the Physics Commissioning Stage is to verify neutron physics characteristics and selected safety functions which depend on neutron physics characteristics. The Physics Commissioning Stage is split into two separate sub-stages, as follows:

- fuel loading into reactor core
- first criticality achievement and the other physics commissioning tests performance.

During the Physics Commissioning Stage reactor power must be kept less than 2 % N_{nom}.

2.2 Power Commissioning Stage

The purpose of the Power Commissioning Stage is to verify the design characteristics of the equipment and the design integration of all the systems in stable operation and in the transitional processes. The Power Commissioning Stage is split into seven sub-stages at power levels to 5 %, 20 %, 35 %, 55 %, 75 %, 90 % and 100 % N_{nom}.

3. SCOPE OF MOCHOVCE 3&4 PHYSICS COMMISSIONING

For Mochovce 3&4 Physics Commissioning these tests are suggested:

3.1 Test of the first sub-stage

- Reactor core loading.

3.2 Tests of the second sub-stage

Note 1: The tests below are carried out at the Primary coolant temperature 200 °C

- Reactor first criticality achievement

- Measurement of boric acid critical concentration
- Check of control assemblies coupling with their drives
- Verification of neutron flux measurement system
- Determination of maximum reactor power for physics tests performance
- Measurement of reactor core loading symmetry
- Measurement of control assembly (CA) Group 6 worth and boric acid effectiveness
- Correction of In-Core Measurement System temperatures at isothermal state
- Noise characteristics measurement

Note 2: The tests below are carried out during the Primary coolant heating up from 200 °C to 260 °C

- Measurement of temperature reactivity coefficient
- Measurement of heat losses and thermal capacity of Primary Circuit

Note 3: The tests below are carried out at the Primary coolant temperature 260 °C

- Correction of In-Core Measurement System temperatures at isothermal state
- Noise characteristics measurement
- Measurement of reactivity pressure coefficient
- Measurement of all CA groups by rod drop method
- Measurement of all CA groups by rod drop method with stuck the most effective CA
- Measurement of all CA groups by rod drop method with stuck the most effective CA and shooting one CA from Group 6
- Measurement of CA Group 6 by its inserting into the core
- Measurement of CA Group 6 worth and boric acid effectiveness
- Measurement of „ejected" CA from Group 6
- Measurement of reactivity temperature coefficient at decreased boric acid concentration
- Measurement of transport delay of boric acid delivery in small and large control boron modes
- Calibration of neutron flux measurement equipment up to 1 % N_{nom}
- Measurement of reactivity power coefficient
- Measurement of hydraulic characteristics of Primary Circuit
- Determination of non-uniform flow distribution in reactor core
- Monitoring of radiation situation
- Verification of design requirements on quality of chemical mode of Primary and Secondary Circuits.

4. DOCUMENTATION FOR MOCHOVCE 3&4 COMMISSIONING

In frame of preparation of Mochovce 3&4 commissioning VUJE elaborates approximately 850 commissioning documents (technical reports, test programmes, test protocols, schedules, etc.). The main documents for preparation of Mochovce Unit 3 Physics Commissioning are as follows:

- VUJE Quality Assurance Programme for Commissioning of Mochovce Unit 3
- Commissioning Programme for Mochovce Unit 3

- Physics Commissioning Stage Programme for Mochovce Unit 3
- Test Working Programmes for Physics Commissioning of Mochovce Unit 3.

Note: The same documentation as for Unit 3 will be prepared for Mochovce Unit 4.

4.1 VUJE Quality Assurance Programme for Commissioning of Mochovce Unit 3

The "VUJE Quality Assurance Programme for Commissioning of Mochovce Unit 3" covers the following activities concerning Mochovce Unit 3 commissioning:

- Organizational arrangement of commissioning activities
- Elaboration of test working programmes for commissioning
- Calculation of theoretical data for commissioning tests performance and evaluation
- Verification of controlling and evaluative software for commissioning tests performance and evaluation
- Physics and Power Commissioning tests performance
- Physics and Power Commissioning tests evaluation.

4.2 Commissioning Programme for Mochovce Unit 3

In accordance with regulatory body requirements the "Commissioning Programme for Mochovce Unit 3" is divided into stages and sub-stages, see Chap. 2. A review of the tests results of each sub-stage will have to be completed before continuing to the next stage or sub-stage. In the Commissioning Programme a list of commissioning tests together with a framework commissioning schedule is presented.

4.3 Physics Commissioning Stage Programme for Mochovce Unit 3

In the Physics Commissioning Stage Programme a scope of Physics Commissioning is specified, see Chap. 3. Further there is presented:

- preparedness of documentation before Physics Commissioning
- initial states of systems and equipment before the first sub-stage beginning
- initial states of systems and equipment before the second sub-stage beginning
- tests and operations sequence during Physics Commissioning.

4.4 Test Working Programmes for Physics Commissioning of Mochovce Unit 3

All commissioning tests will be performed in accordance with authorized test working programmes. The preparation of test working programmes, including their verification and approval is defined in the Directive MO34/SM-860: "Non-active Testing and Commissioning" [4] prepared by Mochovce 3&4 Utility.

The prescribed contents of working programmes are as follows:

1. Purpose of the programme
2. Programme tests and their incorporation into Physics Commissioning Stage
3. Unit preparedness
4. Staffing and qualification

5. Instrumentation and technical equipment
6. List of measured values
7. Test No. 1
   7.1. Purpose and objectives of the test
   7.2. Safety measures
   7.3. Initial unit state
   7.4. Readiness of the documentation
   7.5. Personnel instruction (pre-job briefing)
   7.6. Test implementation procedure
   7.7. Final unit state
   7.8. Methodology of test evaluation
   7.9. Acceptance criteria
   7.10. Procedure in case of acceptance criteria non-fulfilment
8. Test No. 2
   8.1 to 8.10 the same as previous test
   ... (Another tests)
9. Specification of responsibility
10. References

As all details about Mochovce 3&4 systems and equipment are not known yet, only available items of the working programmes contents could be prepared so far. These known items are as follows:

- Purpose and objectives of the test
- Acceptance criteria of the test and procedure in case of acceptance criteria non-fulfilment
- Methodology for test performance and evaluation.

The items above were prepared and summarized for all the Physics Commissioning tests in technical reports, which were reviewed and approved by Mochovce 3&4 Utility. This way it was possible in advance to prepare, review and approve some chapters of working programmes.

5. THREE-LEVEL ACCEPTANCE CRITERIA

Test acceptance criteria are the criteria for assessment of the test results. If the criterion has been met, the test is successful; if the criterion has not been met, the test is unsuccessful. For Mochovce 3&4 commissioning, so-called three-level acceptance criteria will be applied as follows: realization, design and safety criteria.

a) **Realization criteria** are the criteria for evaluation of the test from the viewpoint of its realization, i.e. whether all activities and requirements stated in the test program were performed and whether all data that are necessary for the test evaluation were collected.

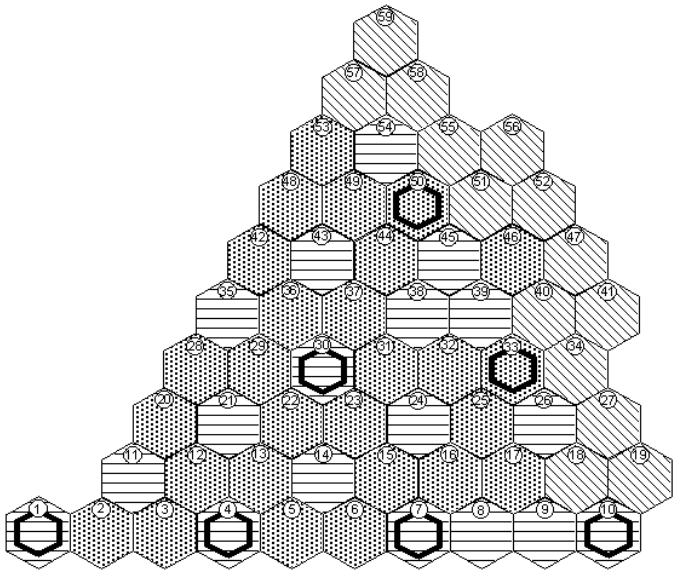
b) **Design criteria** are the criteria used for the evaluation whether the results of the test are in accordance with the NPP design. The design criteria express the acceptable deviation of the measured values from the theoretical values or from the theoretical basic data or from the design requirements for the operation of the tested equipment. Failure to meet the

criteria is usually caused by the measurement error, by the mistake in theoretical basic data or by the incorrect adjustment of the tested equipment.

c) **Safety criteria** are the criteria using for the evaluation whether the results of the test are in accordance with safety analyses specified in the Pre-operational Safety Analysis Report. Any possible failure of meeting the safety criterion indicates a serious problem requiring detailed analyses.

6. PREPARATION OF NEUTRON-PHYSICS CHARACTERISTICS

For the first fuel loading of the Unit 3 reactor core, there will be used fuel assemblies of a new type, which have never been used with Bohunice and Mochovce Units. The scheme of loading according to enrichment is the same as for Bohunice Unit 3, see Fig.1, but the assemblies have the second generation construction. Thus, for the calculations concerning the new fuel, it will be necessary to verify the versions of computing codes BIPR-7 [5] and DYN3D [6] used by VUJE, Inc. The codes BIPR-7 and DYN3D will be verified on the basis of neutron-physics characteristics calculated for the first fuel loading of the Mochovce Unit 3 reactor core, which will be accomplished by the Kurchatov Institute in Moscow. The BIPR-7 code will be verified by comparison with commissioning tests results of Mochovce Unit 2, too.



	Number of FAs / Number of CAs
Enrichment 1,6 %	150 / 12
Enrichment 2,4 %	78 / 25
Enrichment 3,6 %	84 / 0

Figure 1: Loading scheme for reactor core, Mochovce Unit 3, 1st fuel cycle

Based on the scope of the Physics and Power Commissioning tests, the test leaders elaborate requirements for calculations, which will be necessary for implementation and evaluation of given tests.

7. CONCLUSION

The Project "Mochovce 3&4 Completion" is the largest private investment in the history of Slovakia. Costs of the Project should amount to EUR 2.775 billion [7]. The Mochovce Unit 3 will be commissioned in 2012 and the Unit 4 in 2013.

Each Unit of Mochovce 3&4 will have 471 MWe output. Mochovce 3&4 putting into operation will be an ideal replacement for shut down Bohunice Units 1&2. This way Slovakia will be again self-contained and independent in electricity imports in long-term.

REFERENCES

[1] Act No 541/2004 Coll. *on Peaceful Use of Nuclear Energy (Atomic Act)*, September 9, 2004

[2] Decree No 50/2006 Coll. *on details concerning the nuclear safety requirements for nuclear installations in respect of their siting, design, construction, commissioning, operation, decommissioning, and closure of repository, as well as criteria for the categorisation of classified equipment into safety classes*, NRA SR, 2006

[3] NS-G-2.9 *Commissioning for Nuclear Power Plants*, IAEA, 2003

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[5] *Programme BIPR-7*, RNC Kurchatov Institute, Moscow 1995

[6] Grundmann U., Rohde U., Mittag S., Kliem S., *DYN3D Version 3.2– Code for Calculation of Transients in Light Water Reactors (LWR) with Hexagonal or Quadratic Fuel Elements*, Research Centre Dresden-Rossendorf, Inc., Germany, November 2007

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