**FUEL MANAGEMENT TRAINING PLAN**

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| **№** | **Type** | **Topic** | **Time** | **Day** | **Lecturer** |
| **The nuclear physic part of the Busher NPP project** | | | | | |
| 1 | Lecture | **Design basics of the VVER-1000 core**  Main core parts and their characteristics. The discussion of characteristics (geometry, materials) and purposes of main core parts (an assembly; a fuel rod; absorber parts of control rods; burnable absorber rods; upper, bottom and radial reflectors). The description of the core parts design using the general draught. | 10.00-11.00 | 29.05.2017 |  |
| 2 | Lecture | **Neutron physic limitations for normal operation conditions**  The decision of neutron physic characteristics (nomenclature, purpose, verification): fuel burn-up; fuel, fuel cladding and coolant temperatures; integral and local rod power; efficiency of the emergency protection system and control groups; rate of reactivity change; maximum excess of the core reactivity; the degree of core subcriticality under different conditions; negative feed backs | 11.00-12.00 | 29.05.2017 |  |
| 3 | Lecture | **Description of BNPP fuel cycle. Particularities of fuel composition and fuel arrangement in core.**  The following topics will be discussed: FAs enrichment, multiplication factor of FAs depending on fuel burn-up, FAs arrangement in the core and reloading patterns for the first, transient and equilibrium fuel loadings. | 12.00-13.00 | 29.05.2017 |  |
| 4 | Lecture | **Fuel burn-up**  The following fuel characteristics will be discussed: variation of average fuel isotopic composition, burn-up of FAs, burn-up of fuel rods and fuel pellets, burn-up distribution over FA height, burn-up of discharged fuel | 14.00-15.00 | 29.05.2017 |  |
| 5 | Lecture | **Power distribution**  The following characteristics of power distribution will be discussed: relative power of FAs, average coolant heating-up in FAs, axial power distribution in FAs, relative power of fuel rods in FAs, linear thermal power of fuel rods in FAs | 15.00-16.30 | 29.05.2017 |  |
| 6 | Discussion | **Discussion of lectures 1 - 5. Answers to questions of Iranian experts** | 16.30-17.00 | 29.05.2017 |  |
| 7 | Lecture | **Effects and coefficients of reactivity**  Effects and coefficients of reactivity are the characteristics of the core internal nuclear feedback and they are used as input data in design safety analyses. Effect of reactivity associated with a certain parameter defines variation of reactivity, caused by variation of the parameter considered during transition from one state (for example, critical) into another ; and the coefficient of reactivity with respect to this parameter is the ratio of reactivity and parameter variations.  The following characteristics will be discussed : moderator temperature and density coefficients of reactivity , fuel temperature coefficient of reactivity , reactor power coefficient of reactivity and boric acid concentration coefficients of reactivity , reactivity effects in process core heating, burn-up and cooldown | 10.00-11.30 | 30.05.2017 |  |
| 8 | Lecture | **Control of the core reactivity. Efficiency of reactor control and protection systems**  Reactivity control is carried out by two independent systems based on various principles of action - liquid system of boron control and mechanical system of control and shutdown using CPS AR.  The following characteristics will be discussed: critical and subcritical boric acid concentration in different core states, the value of reactivity compensated by BAR bundles, efficiency of the reactor control and protection systems | 11.30-13.00 | 30.05.2017 |  |
| 9 | Lecture | **Stability**  The following topics concerning stability of spatial power distribution will be discussed: stability index, axial stability, diametric stability , azimuthal stability , examples of actual xenon fluctuations | 14.00-15.30 | 30.05.2017 |  |
| 10 | Lecture | **Comparison of calculated and measured neutron physics characteristics of VVER-1000 reactor**  Comparison is usually discussed between calculation and experimental data obtained at reactor start-up (measurements of critical parameters at minimum controllable power level i.e. in HZP state) and following reactor operation at non-zero power levels (indications on day-by-day schedule of the reactor unit power on-loading). At HZP states a comparison are performed for calculated and measured values of critical boric acid concentration, temperature reactivity coefficient and boric acid concentration coefficient of reactivity, integral and differential efficiencies of RCCA groups 9 and 10 and also emergency protection system efficiency. At energy power levels measured and calculated values of critical boric acid concentration and core power distribution are compared | 15.30-16.30 | 30.05.2017 |  |
| 11 | Discussion | **Discussion of lectures 7 - 10. Answers to the questions of Iranian experts** | 16.30-17.00 | 30.05.2017 |  |
| **The analysis of the neutron physic characteristics peculiarities for the VVER-1000 core (is performed on the example of Busher NPP fuel cycle )** | | | | | |
| 12 | Seminar | Modelling of the VVER-1000 reflector using TVS-M code | 10.00-13.00 | 31.05.2017 |  |
| 13 | Seminar | Modelling of the TVS-2M fuel assembly with and without blanket | 14.00-17.00 | 31.05.2017 |  |
| 14 | Seminar | Preparation of BNPP neutronic constant data library for BIPR-7A and PERMAK codes using TVS-M code based on technical specifications and real data of BNPP | 10.00-13.00 | 01.06.2017 |  |
| 15 | Seminar | **The study of the core neutron physic characteristics dependencies**  The study of the core neutron physic characteristics dependencies (criticality parameters, reactivity effects and factors) upon the reactor state parameters (coolant and fuel temperatures, boron concentration in the coolant, excess reactivity compensation method, fuel average enrichment and its burn-up level). This is performed for the first, transient, and steady state loading.  Neutron physic calculations are being performed for different core states when the following parameters are being varied: coolant and fuel temperatures (reactor power), liquid absorber concentration in the coolant, natural boron concentration in BPR. Calculations are performed for different moments of the first, transient, and steady state loading (beginning and end of the campaign). Reactivity effects (temperature, power, poisoning) that occur during reactor heating up (cooldown) and power increase (decrease) are being computed. Reactivity (density, temperature power) factors alteration in dependence with reactor parameters is being studied. The results of the computation performed are being presented in tables and graphs and with short analysis and conclusions. | 14.00-17.00 | 01.06.2017 |  |
| 16 | Seminar | **The study of reactivity regulatory systems efficiency**  The study of the reactivity regulatory systems (boron and mechanical) efficiency due to the reactor parameters (coolant density and temperature, boron concentration in the coolant, average fuel enrichment and burn-up) change. This is performed for the first, transient, and steady state loading.  Neutron physic calculations are being performed for different core states with the following varying parameters: coolant and fuel temperature (reactor power), liquid absorber concentration in the coolant. The calculations are performed for the first, transient, and steady state loading (beginning and end of the campaign). The effectiveness (differential and integral) of different control rod groups and emergency system is being computed. Boron regulating system effectiveness is being computed. The results of the computation performed are being presented in tables and graphs and with short analysis and conclusions. | 10.00-13.00 | 02.06.2017 |  |
| 17 | Seminar | **The study of feeding fuel composition influence**  The study of the influence that the feeding fuel composition (average enrichment, number of fresh fuel assemblies, assemblies enrichment nomenclature) and the core layout principle has on the neutron physic characteristics of the core. It is being performed for steady state loading.  On the example of steady state loading the dependence of neutron physic characteristics (power distribution, power density irregularity coefficients, control rod effectiveness, campaign time, fuel burn-up) upon fresh assembly number, their enrichment, and fuel core repositioning scheme is being studied. The results of the computation performed are being presented in tables and graphs and with short analysis and conclusions | 14.00-17.00 | 02.06.2017 |  |
| 18 | Seminar | **The analysis of space xenon fluctuations**  The analysis of the core stability during space xenon fluctuation appearance. It is being performed for the first and steady state loading. For the first and final moments of the first and steady state campaigns the core stability during free space xenon fluctuation appearance, that is caused by means of turbulence introduction (power maneuvering, control rod movement), is being studied. Amplitude and fluctuation period are being computed. The results of the computation performed are being presented in tables and graphs and with short analysis and conclusions | 10.00-13.00 | 05.06.2017 |  |
| 19 | Seminar | **The study of mechanical regulatory system effectiveness**  The study of mechanical regulatory system effectiveness in dependence on control and protection system control rods number, their position in the core, and group distribution by their functions. Is being performed for the first and steady state loadings.  The mechanical regulatory system effectiveness is being studied in dependence on the control rods number (minimum and maximum number of control rods is 61 and 121 accordingly). The minimum necessary control rods number to provide the emergency system functions is being determined. The variants of control rods gathering into groups are being analyzed taking into account groups’ functional purposes. The results of the computations performed are being presented in tables and graphs and with short analysis and conclusions | 14.00-17.00 | 05.06.2017 |  |
| 20 | Seminar | Practical examples of comparison of calculated and measured neutron physics characteristics of BNPP UNIT 1 by PIR code | 10.00-13.00  14.00-15.00 | 06.06.2017 |  |
| 21 | Discussion | **Discussion of seminars 12-20. Answers to questions of Iranian experts** | 15.00-17.00 | 06.06.2017 |  |
| **Development of reactor VVER-1000 fuel cycles variants on the examples of BNPP using PROROK-A code** | | | | | |
| 22 | Seminar | **Research of flexibility of Bushehr NPP fuel cycle**  Research of opportunity of single variation of cycle duration within the limits of 250-350 EFPD. Research of opportunity of prolongation of a cycle due to work on the lowered parameters.  The analysis of opportunity of compulsory reduction of cycle duration | 10.00-17.00 | 07.06.2017 |  |
| 23 | Seminar | **Development of fuel cycle with increased cycle duration (~ 8000 EFPD)**  Development of a fuel cycle, including the first, transient and equilibrium loadings. Parameters of fresh fuel for the first, transient and equilibrium cycles (fuel enrichment, arrangement of fresh fuel in a core) and BA rods (number of rods, absorber concentration) will be determined. Main neutronic characteristics of the core will be calculated. | 10.00-13.00  14.00-16.00 | 08.06.2017 |  |
| 24 | Discussion | **Discussion of seminars 22 and 23. Answers to questions of Iranian experts** | 16.00-17.00 | 08.06.2017 |  |
| **Preparation of in-core fuel management reports for cycle 4 Unit 1 BNPP** | | | | | |
| 25 | Lecture | **Preliminary Fuel Management Report (PFMR). Fuel Management Report (FMR)**  In accordance with the content of PFMR and FMR. | 10.00-11.00 | 09.06.2017 |  |
| 26 | Seminar | **Performing calculations and preparation of PFMR and FMR**  In accordance with the content of section 3 – 6 of FMR. | 11.00-17.00 | 09.06.2017 |  |
| 27 | Lecture | **Nuclear Design Report (NDR)**  In accordance with the content of NDR. | 10.00-11.00 | 13.06.2017 |  |
| 28 | Seminar | **Performing calculations and preparation of NDR**  In accordance with the content of section 3 – 6 of NDR | 11.00-17.00 | 13.06.2017 |  |
| 29 | Lecture | **ALBUM of neutron-physical characteristics**  In accordance with the content of section 3 – 11 of ALBUM | 10.00-11.00 | 14.06.2017 |  |
| 30 | Seminar | **Performing calculations and preparation of Album sections for BNPP cycle**  In accordance with the content of section 3 – 11 of ALBUM | 11.00-16.00 | 14.06.2017 |  |
| 31 | Discussion | **Discussion of seminars 25 and 30. Answers to questions of Iranian experts** | 16.00-17.00 | 14.06.2017 |  |
| 32 | **Answers to questions of Iranian experts on all training program** | | 10.00 – 17.00 | 15.06.2017 |  |
| 33 | **Tests for Iranian experts** | | 10.00-17.00 | 16.06.2017 |  |
| 34 | **General discussion. Signing of Protocol. Certificate Ceremony** | | 10.00-13.00 | 19.06.2017 |  |