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RELAP5-3D Code Applications for RBMK-1500 Reactor Core Analysis

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Abstract

The RELAP5 code originally was designed for PWR type reactors to provide the US Government and industry with an analytical tool for the independent evaluation of reactor safety through mathematical simulation of transients and accidents. The overall objective of this work was, using the RELAP5-3D code, to develop models for RBMK-1500 reactors of Ignalina NPP for use in integrated thermal-hydraulics-neutronics calculations for the analysis of specific transients in which the neutronic response of the core is important. A successful best estimate RELAP5-3D model of the Ignalina NPP RBMK-1500 reactor has been developed and validated performing a certain set of transient calculations, where real plant data was available for comparison. At first the thermal-hydraulic part of the code was tested. Later, both (thermal-hydraulic and neutron-kinetic) coupled parts of the code were validated. This validation was performed by modeling four benchmark problems that are discussed in detail in this paper. The four benchmark problem analyses reported here are: single control rod spontaneous withdrawal, group of control rods spontaneous withdrawal, feedwater flow perturbation and reactor power reduction transients.

Inadvertent withdrawal of a single control rod as well as a group of control rods were the first two benchmarks modeled during the validation of RELAP5-3D code for RBMK-1500 reactor core analysis. The real plant data on this subject was not available, so the RELAP5-3D calculation results were compared to the calculation results obtained using STEPAN code. Single control rod spontaneous withdrawal benchmark assumed continuous withdrawal of a single control rod out of the core with the velocity of 0.4 m/s. Full withdrawal of the selected control rod lasted ~14 seconds. Single control rod spontaneous withdrawal was modeled with full scale local automatic control (LAC) system operation and without reactor scram activation. Comparative calculations of a single control rod withdrawal out of the core carried out by STEPAN and RELAP5-3D codes, showed reasonable agreement of the calculation results. A group of control rods spontaneous withdrawal benchmark assumed continuous withdrawal of a group of four manual control rods out of the core with the velocity of 0.4 m/s. Full withdrawal of the selected control rods lasted ~13÷16 seconds. A group of control rods spontaneous withdrawal was modeled with reactor scram activation and full scale LAR system operation. Comparative calculations of the withdrawal of a group of four manual control rods by STEPAN and RELAP5-3D codes showed minimal qualitative and quantitative results coincidence for this transient.

The third and the fourth benchmarks were modeled using the RELAP5-3D code and the calculation results compared to the calculation results obtained using the STEPAN code, as well as to the experimental data registered by the TITAN information computer system at Ignalina NPP. Relative to the feedwater flow perturbation transient, dynamic calculations to repeat the experimental results for void reactivity coefficient measuring were performed for Unit 2 (on November 26, 1998) core conditions. During

this experiment feedwater flowrate increased by 200 tons per hour. This inserted negative reactivity into the reactor core. Negative reactivity was compensated by 4 automatic control rods. The fourth benchmark modeled reactor shutdown, which is a regular reactor operation procedure during the lifetime of the reactor. Usually it starts by scram signal activation by the operator. On March 29, 1999 Ignalina NPP Unit 2 was shutdown by the operator signal. After this signal all 24 fast acting scram rods were fully inserted into the reactor core in ~6 seconds from the top end switch position, while all the rest control rods were fully inserted into the reactor core later in ~13 seconds from their present actual operation positions. The above described control rod insertion caused a sharp decrease of reactivity and in total reactor core power. In general, RELAP5-3D and STEPAN codes gave reasonable mutual coincidence of the calculation results for the third and the fourth benchmarks and the reasonable agreement of the calculation results with the available experimental data.

RELAP5-3D calculations were performed by LEI staff in Kaunas (Lithuania), while the STEPAN calculations were performed by RRC “Kurchatov Institute” staff in Moscow (Russia). For the comparison of the benchmark calculation results, the aim was set to compare the calculation results obtained using both codes mainly qualitatively, to see the trends of the calculation results and to get the feeling about the suitability of the codes to model different transient processes taking place in RBMK-1500 reactors. Both codes proved to be able to reproduce experimental results with certain accuracy. Regarding the control rod spontaneous withdrawal benchmarks - the calculation results produced by both codes are only in minimal agreement among themselves. The proposal for the future would be to proceed with benchmark calculations using RELAP5-3D code for the transients taking place in RBMK-1500 reactors and especially for the cases, where experimental data from the Ignalina NPP is available for comparison with calculation results.

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