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RELAP5/MOD3.2 investigation of a VVER-1000 MCP switching on Benchmark problem

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Abstract

This paper provides comparisons between experimental data of Kozloduy NPP "MCP switching on when the other three MCP are in operation", with Relap5 calculations. The investigated thermal-hydraulic driven transient is characterized by spatially dependant non-symmetric processes. RELAP5/MOD3.2 computer code has been used to simulate the investigated transient. Operational data from Kozloduy NPP have been used for the purpose of assessing how the RELAP5 model compares against plant data. During the plant-commissioning phase at Kozloduy NPP Unit 6 a number of experiments have been performed. One of them is switching on MCP when the other three MCPs are in operation. The event is characterized by rapid increase in the flow through the core resulting in a coolant temperature decrease, which leads to insertion of positive reactivity due to the modeled feedback

Abbreviations: ANL, Argonne National Laboratory; BAS, Bulgarian Academy of Sciences; BOC, Beginning of cycle; BRU-A, Steam dumping device to the atmosphere; BRU-K, Steam dumping device to the condenser; EFPD, Effective full power days; EFW, Emergency feed water; EHRS, Electro-hydraulic regulative system; EHTC, Electro-hydraulic turbine controller; FWP, Feed water pump; INRNE, Institute for Nuclear Research and Nuclear Energy; INSP, International Nuclear Safety Program; KNPP, Kozloduy Nuclear Power Plant; MCP, Main coolant pump; MSH, Main steam header; NFMS, Neutron flux monitoring system (in-core reactor control system); NPP, Nuclear power plant; PRZ, Pressurizer; RPLC, Reactor power limitation controller; RPC, Reactor power controller; SG, Steam generator; TG, Turbo generator; UES, Universal electronic system; WP-1, Warning protection.

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mechanisms. The main purpose of this investigation was to improve the discrepancy between the calculations and the plant data. The sensitivity calculation investigates the mixing in reactor vessel and influence of heat structure on the hot legs temperature. The areas of improvements to the Relap5 model are:

- The non-symmetrical mixing in downcomer and reactor vessel annular exit.
- The influence of heat structure temperature on the time delay for equipments measurements.
- Investigation of pressurizer water level – using the hot legs temperature correction.

The RELAP5/MOD3.2 model of Kozloduy NPP VVER-1000 for investigation of operational occurrences, abnormal events, and design basis scenarios have been developed and validated in the Institute for Nuclear Research and Nuclear Energy – Bulgarian Academy of Sciences (INRNE-BAS) Sofia, and Kozloduy NPP. The model provides a significant analytical capability for the specialists working in the field of NPP safety.

This investigation is a process that compares the analytical results obtained by the RELAP5 computer model of the VVER-1000 against the experimental transient data received from the Kozloduy NPP Unit 6. The comparisons indicate good agreement between the RELAP5 results and the experimental data. The sensitivity investigation improves the discrepancy between the calculation and the plant data.

This investigation was possible through the participation of leading specialists from Kozloduy NPP and with the support of Argonne National Laboratory, under the International Nuclear Safety Program (INSP) of the United States Department of Energy.

1. Introduction

This investigation was initiated to define a benchmark problem for validation of thermal-hydraulics codes for application to Soviet-designed VVER-1000 reactors based on actual plant data. This task has been enveloped in the INSP project. Most of the standard problems used in this validation program are based on test data from experimental facilities rather than plant transient measurements. Therefore, the definition of plant-based standard problems is a valuable addition to the validation database.

The reference power plant for this analysis is Unit 6 at the Kozloduy NPP site (Groudev et al., 1999). Operational data from Kozloduy NPP are available for the purpose of assessing how the RELAP5 model compares against plant data. The reference problem chosen for simulation in a VVER-1000 is a MCP switching on when the other three MCPs are in operation (Groudev et al., 2002). It is an experiment that was conducted by Bulgarian and Russian engineers during the plant-commissioning phase at the KNPP Unit 6 as a part of the start-up tests. The test was done as important to safety of the NPP with VVER-1000, model 320. This event is characterized by rapid increase in the flow through the core resulting in a coolant temperature decreasing, which is spatially dependent.