GENERAL APPROACH TO EMERGENCY OPERATING INSTRUCTIONS ANALYTICAL JUSTIFICATION FOR ZAPORIZHZHYA NPP UNIT 5

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Introduction

Preliminary Symptom-Based Emergency Operating Instructions for the Zaporizhzhya NPP Unit 5 (ZNPP EOIs) were developed in 1996 based on the Emergency Response Guidelines (WOG ERG) designed by Westinghouse for the Beaver Valley NPP (USA). An EOI Technical Basis Document should be developed within the program of implementing new emergency operating instructions at ZNPP. An EOI Analytical Justification Project has been launched in August 2001 at ZNPP to ensure the necessary analytical basis. The reference EOI package developed and implemented at the Zaporizhzhya NPP is supposed to be later on adapted to other Ukrainian NPPs with VVER-1000 reactors.

The general approach and the main stages in performing the analytical justification of the ZNPP EOIs have been identified in Phase 1 of the project [2], which includes the following:

- developing a guideline for the EOI analytical justification;
- identification of existing thermal hydraulic (TH) analyses;
- identification of the needs and bases for the additional analysis;
- identification of system parameters and EOI setpoints to be justified.

Phase 2 of the project intends to carry out an analysis of the additional TH scenarios so as to justify the operator actions, system parameters and setpoints incorporated into the ZNPP EOIs [2] using the RELAP5/MOD3.2 code for the model of ZNPP Unit 5.

Identification of existing TH scenarios

Prior to performing the analysis of the EOI procedures, an evaluation has been made for the main features of the existing TH analysis, which was carried out in the framework of the Safety Analysis Report for the VVER-1000/ V-320 reactors as well as within the Probabilistic Risk Assessment (PRA) and the Design Basis Accident (DBA) Analysis for Unit 5 of the Zaporizhzhya NPP. The Ukrainian experts have also studied the experience that was obtained in performing TH analyses for the EOI validation at the Kozloduy NPP (Bulgaria) and shared with the Zaporizhzhya NPP.

It should be noted that application of the TH analysis performed for the VVER-1000 Safety Analysis Report might be limited for the following reasons:

- documentation of the analysis results is made in an insufficient detail; this applies to documentation of the assumptions used, initial and bounding conditions, model descriptions and the required results;
- an insufficient duration of parameter calculation for a detailed evaluation of the plant response;
- an excessive conservatism of the assumptions used (that is, in too many cases the initiating event includes a loss of AC power);

- no simulation of operator actions is used.

The PRA contains a detailed TH analysis of the plant systems' success criteria [1] for various accident sequences related to the maximum fuel clad temperature of 1200°C. As a rule, this acceptance criterion exceeds, the conditions of a challenge to the Critical Safety Functions in the EOIs. Consequently, many scenarios addressed in the PRA may be partially applied to the technical justification of the CSF Restoration procedures' entry and exit conditions as well as to effectiveness evaluation for some of the operator actions.

As an example, the scenario for a 50 mm break loss-of-coolant accident combined with a failure of the high-pressure safety injection system (HPSI) indicates that the operator has to initiate cooldown via the atmospheric steam dump valves (BRU-A) not later than at 45 min so as to prevent core damage. At that moment the fuel clad temperatures do not exceed 290°C (Fig.1). However, the ZNPP EOIs assume core exit thermocouple temperatures of 390°C as the entry condition for the Core Cooling CSF Restoration procedure. This scenario demonstrates effectiveness of the cooldown strategy but requires a revision of the operator action initiation criteria.

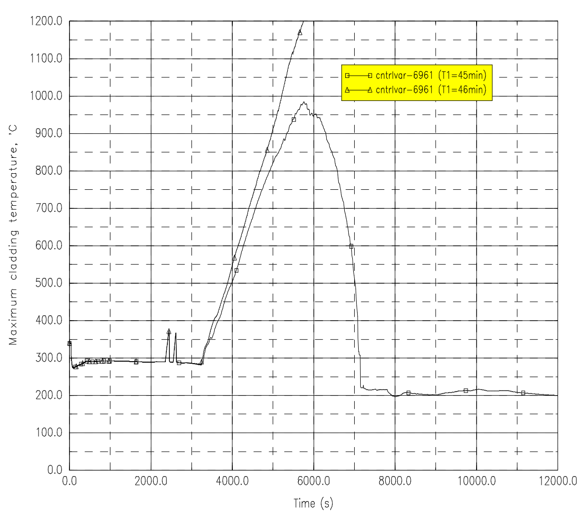

Fig.1 Maximum cladding temperature

The scenario for a total loss of SG feedwater indicates that the operator should initiate Bleed&Feed by use of the RCS emergency vents not later than at 160 min so as to prevent core damage. This scenario confirms effectiveness of the Bleed&Feed strategy under the most adverse conditions (Fig.2) following a complete dry-out of all SGs and a major loss of reactor coolant through the Pressurizer power-operated relief valves (PRZR PORVs).

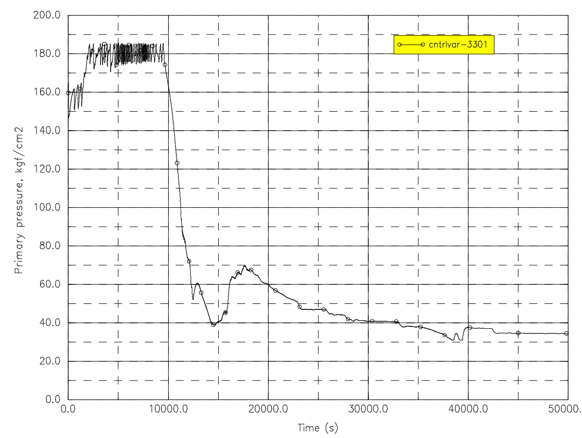

Fig.2 Pressure at the reactor outlet

Because the conditions for implementing this strategy in the EOIs with the challenged Core Cooling CSF are reached at 35 – 40 min, this scenario shows the time reserve for the operator. This scenario may be used to change the Bleed&Feed strategy's criteria as well as to increase the time needed for restoring the feed flow to the SGs.

The examples given above demonstrate the possibility of using the PRA TH scenarios to justify some of the restoration strategies provided in the EOIs.

The PRA also provides an evaluation of the time available to initiate the following operator actions:

- cooldown via the condenser steam dump valves (BRU-K) or the atmospheric steam dump valves (BRU-A);
- restoring SG feed flow from the auxiliary feedwater (AFW) pumps or emergency feedwater (EFW) pumps;
- cross-connecting the EFW tanks;
- transferring the low-pressure safety injection (LPSI) pumps to the residual heat removal (RHR) mode;

- RCS make-up using the boron solution storage tanks;
- starting the high-pressure boron injection (HPBI) pumps;
- closing the main steamline isolation valves (MSIVs);
- emergency venting of the RCS components by opening the YR system's valves (Bleed&Feed mode).

In comparing the above actions to the actions provided in the EOI procedures one can notice that the number of actions in the PRA is limited and conditions for their implementation differ from the criteria used in the EOIs. This fact results from the specific purpose of the PRA and indicates a need for an additional TH analysis to be performed for the EOIs; the scope of such analysis is discussed further in this paper.

The DBA analysis may provide useful technical information despite the fact that the operator actions here are minimal. The DBA analysis addresses representative initiating events, the automatic actions for those events are provided by the design algorithms and duplicated by the operator in the relevant Optimal Recovery EOI procedures. On the other hand, the DBA analysis scenarios may be used for the CSF Restoration procedures to evaluate the Reference Case Scenarios, which demonstrate that the plant meets the acceptance criteria with no operator actions. The DBA scenarios may also be used to show that the design-based accidents do not result in the symptoms of the most severe challenge to the CSF, or that CSF restoration occurs due to automatic operation of the safety systems.

The experience obtained in performing TH analyses for the EOI validation at the Kozloduy NPP can be used:

- to compare some of the strategies in the CSF restoration procedures in performing additional analyses for the EOI validation at the Zaporizhzhya NPP;
- to supplement or confirm the ZNPP's technical information in the process of analyzing the scenarios as well as modeling, and usage of assumptions.

The approach to the EOI analytical justification also presumes the use of operating experience obtained in the incidents and during tests at the units of the Zaporizhzhya NPP. If such data are available then the actual plant response to a transient can be used to verify the results of the analysis or to identify new phenomena, which are not addressed in the current version of the EOIs.

Identification of TH scenarios for the additional analysis

Candidate scenarios and a detailed list of issues to be analyzed have been identified in the step-by-step documentation process for each ZNPP EOI.

The candidate scenarios have been selected for the representative accident sequences and make it possible:

- to confirm acceptability of the entry and exit conditions for a specific procedure;
- to verify effectiveness of the recovery strategies of a specific procedure or, if necessary, to examine new recovery strategies;
- to verify the criteria for operator actions or the setpoints in a specific procedure;
- to evaluate the possibility of a spurious incorrect entry to a specific procedure.

To avoid reiteration of the same analyses for various EOI procedures, the scenarios were grouped based on their generic technical issues and/or the common operator actions in the recovery strategies. The following general issues will be addressed in the process of analytical validation of the EOIs at the Zaporizhzhya NPP:

- the RCP trip/restart criteria;
- the safety injection (SI) termination/re-initiation criteria;
- the safety injection (SI) reduction criteria;
- recovery strategies in the events of a pressurized thermal shock and a cold overpressure condition in the RCS;
- recovery strategies in the event of flow stagnation in the RCS loops;

- natural circulation cooldown;
- the initiation/termination criteria for emergency venting of the RCS components;
- the minimal conditions (number of SGs, SG feed flowrates and levels) required to maintain secondary heat sink;
- the criteria for restricted RCS cooldown/depressurization via the secondary steam dumps;
- the effect of deteriorating containment conditions on instrumentation performance.

The approach to analytical validation of the EOIs is based on the specific purpose of each particular scenario. Depending on the modeling requirements one can use either realistic conditions or conservative assumptions.

If the existing analyses or operational experience indicate that some of the scenarios have been already provided with the necessary calculations, then the priority of their being analyzed for the EOIs becomes lower. The decision as to the necessity of performing additional analyses depends on the importance of the technical issues addressed in each particular scenario.

Unlike the PRA and DBA analyses, validation of the EOI recovery strategies do not aim at a safety analysis of the plant's design; their purpose rather is to confirm effectiveness of operator actions provided by the EOIs when the relevant symptoms occur, regardless of the initiating event.

In order to demonstrate the distinctive features of the approach used to identify the TH scenarios for an additional EOI analysis, we would like to give an example of scenarios developed for the Core Cooling CSF restoration procedures:

Step 1. The entry conditions of this procedure are reached when the core becomes uncovered and the core exit thermocouple temperatures exceed 355°C and 390°C for any of the following representative events:

- loss of reactor coolant combined with a failure of the charging system and the HPSI system;
- total loss of SG feedwater.

The total loss of SG feedwater events result directly in a challenge to the Secondary Heat Sink CSF and are addressed in the appropriate procedures. Therefore, unlike the PRA scenarios, the LOCA events in the EOI scenarios assume availability of the secondary heat sink systems.

Step 2. Recovery strategies considered in justification are as follows:

- re-establishment of HPSI;
- bleed&feed cooldown by use of the SI accumulators, LPSI and emergency venting system;
- SG depressurization to cool down and depressurize the RCS to below the SI accumulator and LPSI shut-off head pressures;
- core cooling by re-starting an RCP.

Step 3. The size and location of the break in the RCS should be evaluated:

- the existing analyses identify a double-ended guillotine break in a cold leg between the RCP and the reactor as the most bounding (in other words the most severe) type of LOCA;
- the break sizes of greater than 100 mm result in primary pressure reduction to below the SI accumulator and LPSI shut-off head pressures, with no actions by the operator; therefore they are of no interest for the EOI validation.

Step 4. To assess the sensitivity of the CSF restoration strategies towards the size of the break, one should evaluate LOCAs with the break size of less than 100 mm (Fig. 3):

- The lower boundary: a non-replenishable loss of coolant with the break size of 20 – 30 mm is selected to evaluate the efficiency of injection by the SI accumulators and LPSI system. The RCS pressure stabilizes at the value of the SG pressures and exceeds the SI accumulator actuation pressure; the SI accumulators remain filled prior to initiation of the strategies.

- A loss of coolant with the break size of 50 – 70 mm is selected to evaluate the efficiency of injection by the SI accumulators and LPSI system. The RCS pressure is below the SI accumulator actuation pressure; a part of the boron solution has already been injected prior to initiation of the strategies.
- The lower boundary: a loss of coolant with the break size of 100 mm is selected to evaluate the efficiency of injection by the LPSI system. The RCS pressure is below the SI accumulator actuation pressure; the accumulators get empty prior to initiation of the strategies.

Depending on the size of the break in the RCS the operator may use various systems to implement recovery strategies such as Bleed&Feed and SG depressurization. Consequently, identification of scenarios for the additional analysis includes a study of the systems that can have an effect on the CSF restoration.

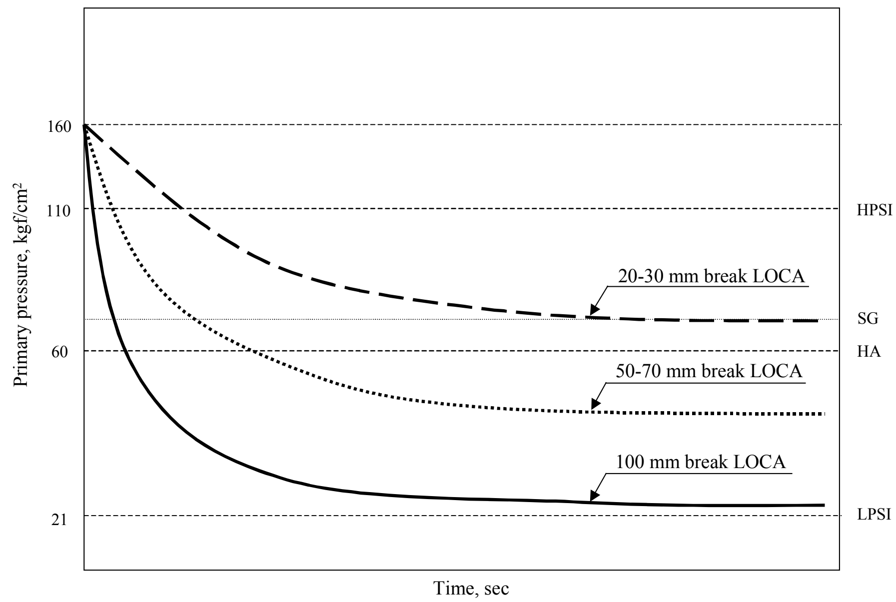

Fig.3 Assessment of sensitivity of the CSF restoration strategies to the size of the break

Conclusion

The analytical justification of the EOIs for the Zaporizhzhya NPP can be implemented by means of integration of the existing analyses made within the In-Depth Safety Analysis Project for the ZNPP with an additional analysis required to evaluate the operator actions as well as the system parameters and setpoints incorporated into the EOIs. This will ensure a higher quality of activities performed in the framework of EOI implementation program.

List of references

1. Analytical Validation of the system success criteria for the PRA of ZNPP Unit 5. A.Bolibok, V. Sverdlov. Obninsk, Russia, 2000.
2. ZNPP EOI Analytical Justification Guideline. ZPG-18. 2001.