Sixth International Exchange Forum
on
"Safety Analysis for Nuclear Power Plants of VVER and RBMK Types"
(Forum-6)

APPLICATION OF THEORY OF CATASTROPHES FOR MODELING OF ACCIDENTAL PROCESS IN VVER SPENT FUEL COOLING POND

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We present an mathematical model and computer code for numerical research of accidental processes in spent fuel cooling ponds. This technique can be used as for analysis of safety of cooling ponds VVER and RBMK-type reactors.
In our work we permit that safety of any artificial system is reliability versus changing of external resources intended for mitigation and compensation of consequences of any accident. By this complex formulation we emphasize different between reliability of any system and safety.
Talking about any nuclear system we must focus primarily on so-called external safety. I.e. on possible influence of accidental processes of environment.
It is obvious that procedure of sustaining and proving of level of safety can be reduced to procedure of proving of sufficiency of barriers of safety in any accidents.
In analysis of safety traditionally it's allocated two level of criteria. First of them is criteria of reasonable risk, but the second is deterministic criteria of impossibility in any cases of becoming such consequences which can be recognized as catastrophe.
We can formulate several principles of development of such models.

- Modeling should be carried out as set of coupled processes.
- All simple process should be modeled by very trying out codes and algorithms.
- Codes and models should be able to simulate accident process completely.

Here we did not do any assumptions about scenario of accidents. But it is very important part of safety analysis. Moreover probable scenario or set of scenario is not alone. There are unlimited set of them. And due to this fact it is impossible to explicitly predict which of them will be realized in accident.
In addition we must note that in modeling and in physics of coupled accidental processes in nuclear systems will be uncertainties, which never can be overcome completely.
Thus we have got for modeling of accidents and their consequences uncertainties both in scenario of events and physical models of elementary processes.
This problem usually is solved by estimating of set of ultimate accidental states of system, which allow then to analyses of value and resistance of safety barriers such as covers, cooling systems, containment etc.
We offer new mathematical (so-called "soft") model to build accidental states of spent fuel cooling pond of VVER and RBMK-type reactors.
Making of equation in lumped parameters we could describe all uncertainties in initial data (scenario) and in physical parameters (data and models of processes) as managing parameters (in optimization procedure).
First of all we reduced very complex coupled model of fuel behavior and four-fields model of thermal hydraulic of two-phases media (boiling coolant) to "soft" model in

lumped parameters with functional interface which can be recognized as independent managing parameter (or parametrical function).
By constructing of complex coupled model of neutronics, thermal hydraulic and resistance of fuel pin we made code, which can be used for provable estimation of ultimate characteristic of cooling pond in severe criticality accidents.
For example we describe three variants of accidents in cooling pond with spent fuel of VVER initiated by falling or immersing of fuel assemblies in cooling pond and stopping of coolant circulation.
The offered technique is based on general view decisions and excludes necessity of detailed modeling of real scripts of emergency process.
The basic requirements to models:

- structural stability;
- informative and stability;
- an opportunity of check of separate elements of model.

Models:

- dynamic model in lumped parameters of process including neutronics, thermal hydraulics of two faze flow, fuel pin behavior;
- research of real scripts of failure is replaced with search of the maximal consequences of failure;
- results of calculation are the initial data for designing barriers of safety;
- stochastic optimization algorithm;

Results

- "soft" (on V.I.Arnol'da's classification) model;
- it is shown, that search of the heaviest failure and a substantiation of conservatism of estimations is a not trivial problem.

Field of applicability

- The formulation of criteria of similarity for a substantiation of safety (search of the decision on " a surface of the maximal damage ");
- Practical calculations of sufficiency of design means of protection.

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