

COMPARATIVE EVALUATION OF TWO APPROACHES TO THE FIRE HAZARD RISK MANAGEMENT IN THE NUCLEAR POWER PLANT KOZLODUY, BULGARIA

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Abstract. The fire hazards risk management in nuclear power plants is extremely important in aspect of transboundary pollution, because it may lead to a nuclear accident. A comparison is made between the probability and deterministic approaches in evaluation of the fire hazard as a main problem of the safety of the nuclear power plant Kozloduy, Bulgaria. The basic international principles concerning the prevention and protection measures for fire safety of atomic power stations are presented. Both approaches are applied concerning the methods of analysis and management of fire risks at such sites. The paper contains analysis and evaluation of the measures taken for limiting the fire hazards in the nuclear power plant Kozloduy, Bulgaria for the last ten years. Conclusions are made about the quality and the quantity of the preventive and protective measures concerning the fire hazards at the premises.

Keywords: fire hazards, risk management, deterministic analysis, probability analysis, nuclear power plants.

AIMS AND BACKGROUND

Among the most important direction of development of the science and technology, during the last 50 years, is the atomic energy. The production of electricity at present by nuclear power plants (NPP) covers 1/10 of the world production. In Bulgaria are operating 6 nuclear reactors within the site of NPP Kozloduy with total installed output of 3760 MW. The first four reactors are VVER-440-type 230 having a horizontal steam generators. There the cooling of the nuclear reactor (water – water type) is carried out by six primary coolant loops. Among the principal deficiencies were considered the Accident Localization System, safety and fire-protection systems^{1,2}. The fifth and sixth reactors are VVER-1000-type 320 having steel-lined, pre-stressed, large volume concrete containment structure with horizontal steam generators. The cooling of the nuclear reactor is carried out by four coolant loops^{1,2}. They have a high level of internal safety. Among the princi-

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pal deficiencies were considered the wiring and emergency electrical system and reactor-protection system which did not meet Western standards for separation – control and safety functions are interconnected and ways that may allow failure of control system to prevent operation of a safety system².

One of the most important systems ensuring the safety of NPP is the fire hazard risk management. Its main purpose is to secure the necessary prevention and protection level of fires in NPP Kozloduy during its operation and transportation, storage, processing and handling of nuclear wastes³.

The purpose of the present paper is to compare the results of two different approaches for fire hazard risk management on the basis of analysis of the results obtained during risk inspection report. Special attention is paid to the wiring channels, where control and safety functions might be interconnected.

Another aim is to compare these results with the improvement recommendations made by the International Atomic Energy Agency (IAEA).

RESULTS AND DISCUSSION

The substantial analysis of the fire safety contingency plans of NPP Kozloduy shows that it is based on the following basic principles, which are in accordance with the regulations of IAEA:

- securing a safe closing of each nuclear reactor and keeping it in under-critical conditions in case of fire;
- prevention of bursting of fires with the help of organizational and technical measures;
- limitation of spreading of fires by keeping the safe distances between the different buildings on the site and protection by fire walls and other physical barriers;
- fast discovering and extinguishing of the fires after they have burst out with the help of organizational and technical measures.

The control of the fire safety in NPP Kozloduy is conducted on the basis of a mixture of international, state and internal standards.

The basic organization for international control of NPP Kozloduy concerning the fire safety is IAEA. The representatives of the World Association of the Nuclear Operators (WANO) carry out the inspection visits.

The results of the analysis show also that the changes made in the fire safety in NPP Kozloduy have transformed its effectiveness as a main task for its management. A large scale measures have been taken for transformation of reactors 1–4 in accordance with the recommendations and requirements of IAEA. These transformations are carried out on the basis of the probability and deterministic analyses of the fire safety.

a) *Probability analysis.* The probability analysis is based on the tree of events (failures). The logic scheme according to which it is carried out for one site of NPP is shown in Fig. 1. The results after differentiation of the fire compartments (part of the building including one or more rooms separated from the others with fire walls and/or enough spacing⁵) are containing the determination of the following parameters:

- type of the equipment and the fire load on the basis of the materials stored in this compartment, probable reasons for ignition;
- fire hazard and the exact place where a fire can start;
- routes for spreading of a fire;
- loss sequences after materializing the scenario (full description of losses);
- active and passive systems of fire protection;
- conditional probability of melting of the active nuclear reactor zone after materialization of the scenario;
- list of the equipment in the fire compartment which are included in the probability analysis model, affected after the materialization of the scenario;
- influence of the scenario on the productivity of the machines and on the NPS as a whole;
- frequency of materialization of the scenario;

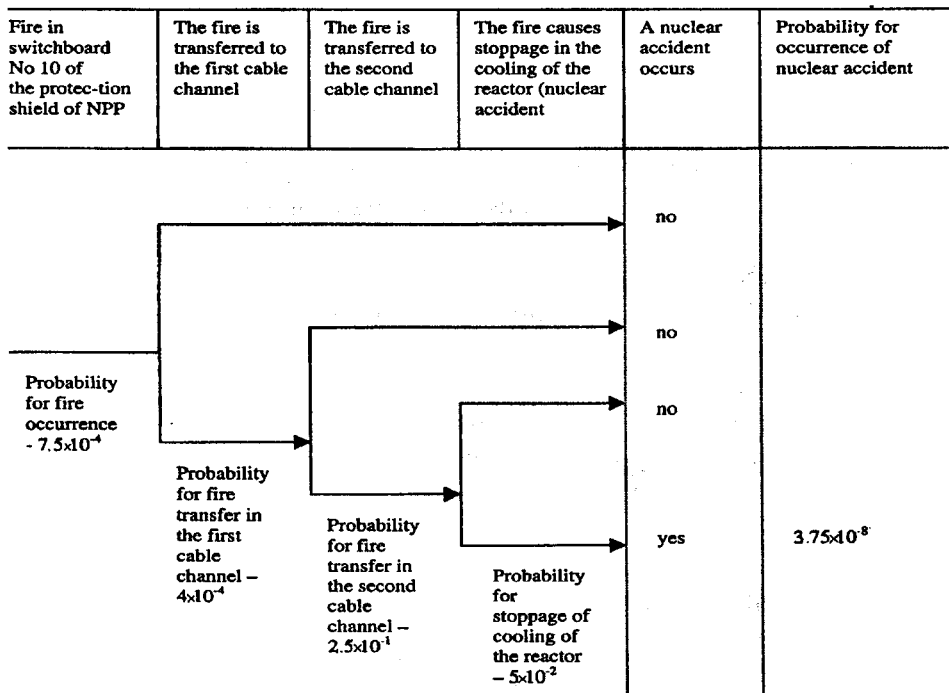


Fig. 1. Scheme of the probability analysis used in the present studies. The assumption is that a fire has started in one of the switchboards of the protection shield

– “unconditional” frequency of melting of the active zone (frequency of melting of the active zone, when the frequency of materializing of the respective scenario of ignition and development of fire are taken into account).

When probability analysis of fire hazards is carried out we have taken into account the different hypotheses. For example, the one which includes that the systems for fire extinguishing are not functioning, so the fire is spread in the whole fire zone. As a result of this assumption we have increased the values of the existing fire hazards.

The calculations, carried out according to the method discussed above, show that the fire safety of the reactors VVER-430/230 (taking into account their principal deficiencies given in Refs 2, 6) is with overall frequency of 10^{-6} times per year for losing of active zone control due to fire. This level fully corresponds to the requirements of IAEA for the fire safety of NPP.

b) Deterministic analysis. As a basis of the deterministic analysis of the fire hazard in NPP Kozloduy serves the evaluation of the ignition sources and development of fires in the respective fire compartments in the buildings. The effectiveness of the active and passive systems for fire protection is taken into account, attention is paid to the protection of the control and power cables, supplying electricity to the safety machinery and equipment.

The deterministic analysis of the fire safety was carried out according to the scheme given in Fig. 2. It gave us the possibility to found out the possible denials for general reason in case of bursting a fire (denial caused by fire, which can impede from functioning certain safety system) in the nuclear reactor building, the diesel generators, pumping station for fire water, technological and electrical communications.

This analysis includes the following:

- description of the rooms and calculation for everyone of them the amount of the fire load and the existing fire protection measures;
 - differentiation of the fire compartments and sectors;
 - calculation of the failure risks for general reason in the fire compartments.
- As possible failure for general reason is taken, the assumption that in fire compartments are present: mechanical equipment or electrical connections of the doubled channels of one and the same safety system; mechanical equipment or electrical connections, part of the channels of the system, having safety functions, which are also part of the double channel; electrical connections which are included in the categories mentioned above, but are supplied with energy by the doubled electrical safety switchboards (middle voltage – low voltage) and they are in such amount that the selectivity of the protection included in these switchboards can be broken;
- functional analysis of the fire losses and suggestions for the fire hazard contingency planning.

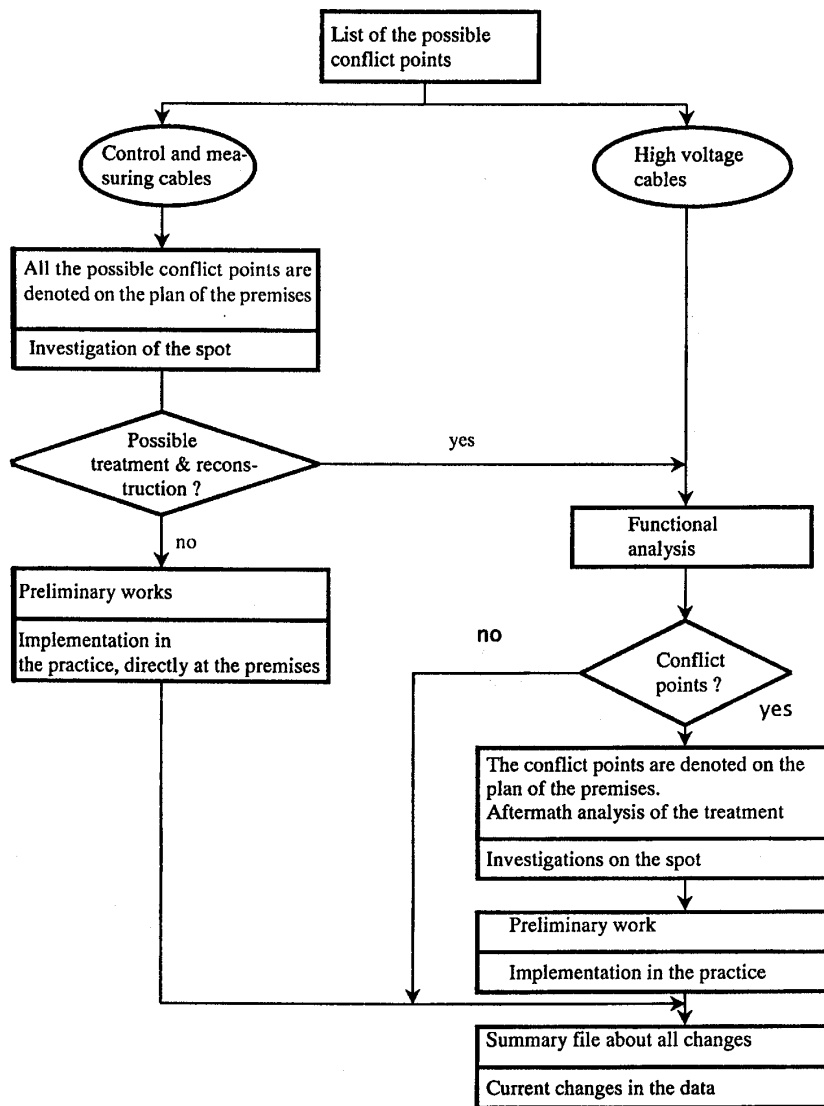


Fig. 2. Scheme of the deterministic analysis for fire risk evaluation, used in the present studies

After the differentiation of the fire compartments on the basis of heat capacity of the burning materials in the rooms, the fire load is determined and on its basis the fire development time and the maximum temperature which can be reached. After the specification of the systems having safety functions in each

room of the fire compartment, a functional analysis of the conflict points of the power and control cables was carried out. By definition, for the conflict points in certain fire compartment of zone are taken into account the following criteria:

- Criterion (a) for the electric connections, adjacent to the doubled channels of one and the same safety system;
- Criterion (b) for the electric connections, adjacent to one of the double channels of one safety system or to a system necessary for its functioning in the doubled channel;
- Criterion (c), which combines the electric connections, adjacent to a channel different from those of the respective fire compartment, independently for the same or other protection system.

On the basis of the obtained results by the risk analysis for the sites of NPP Kozloduy are suggested the following risk improvement proposals in the following main directions:

- increasing of the fire-resistance and decreasing the fire load (improvement of the fire resistance of certain elements of the construction, additional building of fire walls, changes in the fire doors, increase of the fire resistance of the cable channels, covering of the electric cables with fire resistant paint, etc.);
- increasing the fire resistance of the ventilation (introduction of new fire resistant valves in ventilation channels, change of the oil filters with fire resistant ones, etc.);
- introduction of new automatic fire alarm and fire fighting systems, connection of the of the water fire water rings for nuclear power reactors I – IV and V and VI);
- improvements in the evacuation schemes;
- improvements in the maintenance procedures of the fire protection system.

CONCLUSIONS

The fire risk evaluation carried out by the two approaches given above was used for giving risk improvement proposals to NPP Kozloduy. The measures taken on its basis for increasing of fire safety are giving us reason for the following conclusions to be made:

1. The increase of the fire safety of NPP Kozloduy is a priority of the its management.
2. The fire safety system in NPP Kozloduy is corresponding to the requirements of IAEA for fire protection measures in nuclear power plants. The fire safety system secures good level of fire safety during its work and also in the phases of transportation, storage and processing of nuclear wastes.
4. After 1991 in NPP Kozloduy a significant improvement has been made in the fire safety of the plant. As a result of recommendations of the analyses and

expertise measures have been taken for improvement of the reliability, effectiveness and protection as of the safety systems so to these of normal processes, important for the safety of the plant.

5. NPP Kozloduy has well organized, equipped with modern fire fighting facilities fire brigade. In some points it is better trained and has more resources than the fire brigades in most of the developed countries in the world.

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