Comparison between the deterministic rules in fire protection of nuclear power plants with a quantitative analysis on the basis of a concrete example

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Abstract: **This article is a summary of a study concerning the comparison between the design of the fire protection in nuclear power plants based on deterministic rules and a performance-based analysis. The comparison is done on the basis of a concrete example.**

I. INTRODUCTION

Today the design of most nuclear power plants is based on the U.S. Nuclear Regulatory Commission (NRC) framework.

This framework is based on deterministic rules based on a defense in depth concept that is commonly recognized as a safe method to maintain the safety goals.

There is now a movement to introduce performance-based analyses into fire protection engineering practice and in 2002, the National Fire Protection Association (NFPA) developed NFPA 805, *"Performance- Based Standard for Fire Protection for Light-Water Reactor Electric Generating Plants"* that since then has been twicely revised.

The goal of the study is to compare the deterministic and the performance based approach on a diesel generator room

II. NFPA 805

The NFPA 805 takes four goals into account: the nuclear safety, the radioactive release, the life safety and plant/damage business interruption.

The NFPA 805 methodology allows to choose between a deterministic approach and a performance based.

Nevertheless there are common parts to the two approaches that have first to be completed: the establishment of fundamental fire protection program and elements as well as the identification process.

III. IDENTIFICATION PROCESS

In the identification process several steps needs to be performed before to choose between both approaches:

- Identify fire area boundaries and fire hazards
- Identify performance criteria to determine if the design will satisfy
- Identify structures, systems or components (SSCs) to which the performance criteria apply

In the study discussed in this paper, a diesel oil fire is examined.

All performance criteria apply except the radioactive release. Indeed diesel generators are vital auxiliaries for the nuclear safety, they are generally not installed in nuclear restricted areas, provisions shall be made to safely extinguish the fire and, losses and business interruption shall be kept to a minimum.

The fire walls, redundant fire safety cables and a solid-state control component on a major mechanical component are identified as nuclear safety components. The tenability conditions for fire-fighters are also assessed.

IV. DETERMINISTIC APPROACH

The deterministic approach in this study is based on:

- the RG 1.189 – "Fire Protection for Nuclear Power Plants"

- the "International Guidelines for the Fire Protection of Nuclear Power Plants"

The application of the deterministic approach has demonstrated that the approach is straightforward and doesn't need a high level of expertise and that the requirements are well specified but sometimes without statement of clear objectives.

There are also no considerations for cost-effective designs, almost no possibilities to implement alternative designs or to justify (code) deviations and no evaluation of safety margins.

A fire hazard analysis should also be performed to demonstrate that the design of the fire protection meets the nuclear safety and radiological releases objectives. These analyses need a quantitative approach.

V. PERFORMANCE BASED APPROACH

The performance based approach requires the use of fire simulation models but doesn't provide a detailed fire model process. Therefore in this study the NUREG 1934: "Nuclear Power Plant Fire Modeling Application Guide" has been used.

VI. FIRE MODELLING PROCESS

The fire modelling process has been applied to the diesel generator room with the use of 3 different models: FDT (algebraic model), MAGIC (two-zones model), FDS (CFD model).

With the use of the models it has also been verified if there are no to high safety margin implemented in the deterministic approach. Therefore redundant SSC where placed in the same rooms without fire extinguishing systems and presence of a fire in between them.

The analyses have demonstrated that in comparison to the deterministic approach, the performance based approach establishes clear objectives and leaves it to the designer to achieve them. This allows cost-effectiveness, flexibility and determination of the safety margins in the design.

Nevertheless the determination of the safety criteria and damage criteria is not straightforward and these are uncertain due to lack on reliable data. In addition the models need to be verified and validated in order that their own uncertainty can be quantified and reduced.

The set up of the models and the interpretation of the results requires also a specific education, skill and experience.

Due to the lack of exact information's (geometry, fire loads, positions of SSC's, operational conditions) in the early design stage, it's not easy to set up useful models.

Finally the calculations have also proven in this example by contradiction that SSCs need to be separated by fire barriers or that a fire suppression system is needed when they are only separated by distance.

V. CONCLUSIONS

Both approaches have their advantages and drawbacks but on the basis of the study it can be concluded that it is much easier to start the design with a deterministic approach and when needed to switch later in the design to the performance based approach i.e. for cost-effectiveness needs, justification of deviations or determination of safety margins.