PSA SIGNIFICANCE OF EVENTS WITH ELECTRICALLY INDUCED HIGH ENERGY (ARCING) FAULTS

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INTRODUCTION

- International operating experience of nuclear installations reveals a non-negligible number of events with explosions and fast fires resulting from high energy arcing faults (HEAF)
  - e.g. induced by electric arcs in circuit breakers, switchgears, etc .
  - leading to partly significant consequences to the environment of these components which exceed typical fire effects
  - event investigations indicating failures of fire barriers and fire protection features due to pressure build-up in the electric cabinets and/or pressure
- Preliminary probabilistic safety assessment of a French event in 2001 resulted in a CDF = 5 E-04/a
- For other events of the same type, CDF between 9 E-05/a and 2 E-03/a were roughly estimated
- A variety of fire protection features may be affected in case of HEAF events by the pressure increase and/or pressure waves ➔
  HEAF events may have the potential of event sequences strongly affecting CDF

PURPOSE OF THE FEEDBACK FROM OPERATING EXPERIENCE (1)

- Identifying potential consequences of HEAF events on adjacent equipment and plant areas exceeding the typical fire effects (smoke, soot, heat, etc.)
- International NPP operating experience reveals reportable HEAF events, e.g. induced by electric arcs in circuit breakers, etc. leading to partly safety significant effects on the environment of these components exceeding typical fire effects
- A German reportable event with actuation of a stationary CO_2 extinguishing system resulted in deterioration and opening of a fire door caused by the overpressure in the compartment ➔
- In-depth investigations on this type of events

PURPOSE OF THE FEEDBACK FROM OPERATING EXPERIENCE (2)

- International experts decision on investigations:
  - Literature studies of events at nuclear installations reported to the national authorities and/or international databases INES (International Nuclear Event Scale) and IRS (Incident Reporting System)
  - Development of a questionnaire providing a list of questions, which mainly shall be answered by the licensees
- By this means it should be possible to evaluate the state-of-the-art to gain insights on the basic phenomena for HEAF and to find out how such events can be prevented in nuclear installations in the future
- Analysis performed on a national basis and internationally by the international experts group
- Insights of the investigations and feedback from the national as well as international operating experience shall be forwarded to the authorities as well as to the licensees

QUESTIONS TO THE LICENSEES ON EVENTS OCCURRED

- Operating Experience
  - Does the operating experience including the external power supply reveal events interconnected to a high energy electric failure of electric components and equipment with voltage ≥ 6 kV?
  - What was the damage? Describe area and extent of the damage (e.g. explosion pressure wave, pressure increase, fire, etc.)
  - In which buildings / compartments / plant areas did the event occur?
  - What type of component was the fault initiated in (e.g., switchgears, breakers, etc.)?
  - What voltage level did the component operate at and what was the nominal current load available to the component?
  - If known, what was the estimated overload voltage/current observed?
  - How was the HEAF observed/detected? Directly by fire detectors, visual or auditory detection in the location where the fault occurred or indirectly by faulty/spurious signals indirect fire alarms, etc.?
  - What was the arcing duration in case of arcing being the cause? How did it stop?

QUESTIONS TO THE LICENSEES (2)

- Consequences
  - What was the damage? Was there high energy impact by electric causes or by others (valves, gases, etc.)? Which components/ types of equipment were affected?
  - What was the damage zone?
  - Did the event affect more than one component (CCF)?
  - Was the damage limited to one fire compartment or were further compartments affected?
  - Which consequences/effects (e.g. pressure waves, impact by missiles, etc.) to adjacent/nearby components (including cables) and compartments / plant areas have been observed besides the typical fire effects?
  - Which pressure peaks/amplitudes and impact durations were measured / observed?
  - Which functions of fire protection features (fire barriers and their elements as well as active means) have been impaired by the effects of HEAF, in particular by pressure waves and missiles?

QUESTIONS TO THE LICENSEES (3)

- Fire Suppression (if applicable)
  - Was fire extinguishing performed?
  - If yes, which extinguishing means were applied? Which were successful?
  - What was the total fire duration?
- Event causes
  - Was it possible to find out the causes of the high energy impacts observed? If yes, what were the potential causes?
  - Were the initial causes man-induced ones or purely technical ones or combinations of both?
  - Have the root causes been found?
  - Which measures have been taken as consequence of the event to prevent recurrence?
  - Was there damage by the high energy release or by fire or by both? What was the damage?

QUESTIONS TO THE LICENSEES (4)

- Measures against Recurrence / Corrective Actions
  - Which measures have been taken to prevent a recurrence of the event?
  - What are the corrective actions after the event?
    - List of actions for the room/compartment or plant areas, respectively
    - Pre-fire planning depending on the equipment present in the room

Questions to the licensees without observations from events

- Preventive measures
  - In which compartments / plant areas are components and equipment available with the potential of HEAF? Are there safety significant / safety related components available in these compartments/plant areas and/or adjacent ones? If yes, which ones?
  - Which measures are foreseen (originally as well as improved ones after the event) to limit the consequences of events with HEAF failures?
  - Can a deterioration of safety related equipment be excluded by the preventive measures?

QUESTIONS TO THE LICENSEES (5)

- Preventive measures (contd.)
  - Which functions of fire protection features (fire barriers and their elements as well as active means) are assumed to be impaired by the effects of HEAF, in particular by pressure waves and missiles?
  - Are further measures (i.e. monitoring, regular in-service inspection, or ageing management) intended for prevention of HEAF events and if yes, which ones?
  - Have measures been implemented for plant improvement/upgrading to prevent those HEAF failure mechanisms, and if yes, which ones?
- Assessment without direct observations from events
  - In how far are such HEAF events and their potential effects taken into account in the deterministic analysis of the installations/facilities?
  - Have the HEAF equipment and its potential failures / HEAF events been considered in the fire PSA? If yes, how and in how far?
  - What are the potential effects of “ageing“ in the context of HEAF of electric equipment and components, can aging be assumed for those components, where such events occurred?

QUESTIONS TO EXPERTS FOR IN-DEPTH ANALYSES

- Are the fire protection features implemented in the nuclear installations designed against the potential effects from HEAF of electric components and equipment or have they been upgraded?
- What is the amount of equipment with the potential for HEAF being present in the nuclear power plant?
- Which pressure peaks/amplitudes and impact durations may occur in the case of HEAF of electric components? Are there calculations/estimates?
- Which insights are available on the HEAF failure mechanisms for electric equipment?
- Are there insights on the basic (mainly physical and/or chemical, electrical) phenomena and the interrelationships?

HEAF OPERATING EXPERIENCE FROM GERMANY (1)

Year of Occurrence	Reactor Type / Plant State	Component / Voltage Level	Damage Limited to Component / Barrier Deteriorated	Fire / Explosion
2007	BWR / FP	transformer / 380 kV	yes / no	E / F
2007	PWR / FP	transformer / 380 kV	yes / no	-
2006	BWR / LP/SD	auxiliary service pump / ?	yes / no	-
2006	PWR / FP	switchgear drawer / ?	yes / no	-
2006	BWR / FP	switchgear drawer / ?	yes / no	-
2005	BWR / FP	switch / ?	yes / no	-
2004	PWR / LP/SD	emergency power feed line / ?	yes / no	-
2004	BWR / FP	diesel generator / 6 kV	no / no	F
2004	BWR / FP	cable connection / ?	yes / no	F
...	...	...	...	...
1977	BWR / LP/SD	emergency switchgear / ?	yes / no	-

HEAF OPERATING EXPERIENCE FROM GERMANY (2)

- In total 35 reportable HEAF events due to German reporting criteria from 1977 up to now
- 10 HEAF with consequential fires
- 2 HEAF events with explosion and fire
- For 7 HEAF events damage was not limited to the component where it started
- For 1 HEAF event a deterioration of barriers has been observed

HEAF OPERATING EXPERIENCE FROM INES AND IRS (1)

Year of Occurrence	Reactor Type / Plant State	Component / Voltage Level	Damage Limited to Component / Barrier Deteriorated	Fire / Explosion
2006	PWR / FP	transformer busbar / 20 kV	yes / no	F
2006	BWR / FP	switchgear station / 400 kV	yes / no	-
2001	PHWR / LP/SD	circuit breaker cables / ?	no / no	F
2001	PWR / FP	power switch / ?	no / no	E / F
2001	PWR / FP	circuit breaker / ?	no / yes	F
2000	PWR / FP	circuit breaker / 6 kV	yes / yes	F
2000	PWR / FP	circuit breaker / 12 kV	yes / no	F
1996	PWR / FP	power switch / ?	no / yes	E / F
1996	PWR / FP	lightning arrester / ?	no / no	F
1995	PWR / FP	circuit breaker / 6 kV	no / no	E / F
1992	PWR / FP	switchgear room / 6 kV	yes / no	F

HEAF OPERATING EXPERIENCE FROM INES AND IRS (2)

Year of Occurrence	Reactor Type / Plant State	Component / Voltage Level	Damage Limited to Component / Barrier Deteriorated	Fire / Explosion
1991	PWR / FP	control cabinet / 6 kV	yes / no	F
1991	PWR / FP	busbar / 0.4 kV	yes / no	F
1990	PWR / LP/SD	switchgear station / 400 V	yes / no	-
1990	PWR / FP	busbar / 6 kV	yes / no	-
1990	LGR / FP	busbar / 6 kV	no / no	F
1989	PWR / FP	circuit breaker / 6 kV	no / no	E / F
1988	PWR / FP	distribution / 13.8 k V	yes / no	E / F
1984	BWR / FP	main transformer / ?	no / yes	E / F
1983	GCR / LP/SD	control panel / 5.5 kV	no / yes	E / F

CONCLUSIONS

- Purpose of the common international project performing in-depth investigations on HEAF events, their causes and failure mechanisms:
  Find out if these events may be significant contributors

- At the actual stage of the investigations evaluating NPP operating experience:
  First indications on the typical event sequences and their potential contribution to core damage

- As soon as answers to questionnaire have been statistically examined / interpreted:
  First rough estimates on the HEAF contribution to CDF

- Investigations may reveal additional findings on the event causes, possible measures either for event prevention or for limiting the consequences such that nuclear safety is not impaired