



Generation of Risk Insights Related to the D3/HFE ISG on Credit for Operator Action

**NRC / Industry Meeting
Digital I&C
January 14, 2008**

Risk Insights from PRA Related to D3 ISG on Credit for Operator Action

- Update of D3 ISG related risk insights (requirement for an automatic DAS for events in which operator action cannot be credited – e.g. Large LOCA, MSLB)
 - Identification of additional benefits associated with a diverse ESFAS
 - Review of spurious ESFAS events from US operating experience to determine applicability to DAS
 - Results of uncertainty analyses and sensitivity studies
- Comparison to regulatory acceptance criteria
- Scope of D3 Evaluations

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- Results presented in July and August '07 were limited to a single PWR
 - Westinghouse plant of recent vintage
 - Transient analysis and uncertainty results borrowed from another plant
 - Initiating event data based on NUREG/CR-5750 (1987- 1994)
- Analysis has been expanded
 - A spectrum of plant types with quantitative results specific to each
 - Initiating event data updated (or is being updated) to reflect NUREG/CR-6928 (1987 – 2004)

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Expanded PWR results

				W 2 loop #2	W 4 loop	CE #1	CE #2	B&W
IE	IE Frequency NUREG/CR-6928	Time to 2200°F	HEP	CDF resulting from digital CCF ($P_{CCF} \sim 1E-4/dem$)				
Large LOCA	1.3E-06/yr	-				1.3E-10		
Med LOCA	5.1E-04/yr	>30m	1E-02			5.1E-10		
Small LOCA	5.8E-04/yr	1h	1E-03			5.8E-11		
SGTR	3.5E-03/yr	>1h	1E-03			3.5E-10		
Pzr SRV	2.9E-03/yr	1h	1E-03			2.9E-10		
Spurious PORV	2.1E-03/yr	1h	1E-03			2.1E-10		
Total						1.6E-09		

← Benefits of a diverse SI

CCDP by plant type						
LOFW		1.3E-06	5.8E-06	5.0E-06	2.0E-06	4.0E-06
General Trans			5.6E-07			
Spurious SI				1.6E-05		3.1E-05

IE Frequency NUREG/CR-5750		Spurious DAS CDF (per year) by plant type				
Spurious ESFAS	0.02/year	2.6E-08	1.1E-08	3.2E-07	4.0E-08	6.2E-07

← Risks introduced by a diverse SI

The benefits of a diverse SI, even for an expanded set of events, do not appear to be cost justified (per criteria of NUREG/BR-0058).

For the spectrum of plants considered, the diverse SI may even have a negative impact on safety.

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Expanded BWR results

				BWR 2	BWR 3/4	BWR 4	BWR 5	BWR 6				
IE	IE Frequency NUREG/CR-6928	Time to 2200°F	HEP	CDF resulting from digital CCF ($P_{CCF} \sim 1E-4/dem$)								
Large LOCA	6.8E-06/yr	-		6.8E-10								
Med LOCA	1.0E-04/yr	25m	1E-02	1.0E-09								
Small LOCA	5.0E-04/yr	1h	1E-03	5.0E-10								
Med/Large SLB	1.0E-4/yr	25m	1E-3	1.0E-11						←	MSIV isolation	
Total				2.2E-09						←	ECCS initiation	
CCDP by plant type												
MSIV Closure				2.6E-06	3.9E-06	6.0E-06	1.4E-06	1.8E-06				
General Trans				7.0E-07	1.1E-06	1.6E-06	7.0E-07	7.6E-07				
		IE Frequency NUREG/CR-5750	Spurious DAS CDF (per year) by plant type									
Spurious MSIV		0.02/year	5.2E-09	7.8E-08	1.2E-07	2.8E-08	3.5E-08			←	MSIV isolation	
Spurious Rx Trip		0.004/year	2.8E-09	4.7E-09	6.8E-09	2.8E-09	3.2E-09			←	ECCS initiation	

The benefits of a diverse ESFAS, even for an expanded set of events, do not appear to be cost justified (per criteria of NUREG/BR-0058).

For the spectrum of plants considered, the diverse ESFAS may even have a negative impact on safety.

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- Sensitivity Studies

$$\text{Risk/Benefit}_{\text{DAS}} = \frac{(\text{IE}_{\text{Spur DAS}})}{(\text{IE}_{\text{LOCA events}})} \frac{(\text{CCDP}_{\text{Spur DAS}})}{(\text{P}_{\text{digital}})}$$

$\text{IE}_{\text{Spur DAS}}$ is several hundred times greater in frequency than the frequency of events benefiting from a DAS (i.e., LOCA events)

$\text{CCDP}_{\text{Spur DAS}}$ is one to two orders of magnitude less than $\text{P}_{\text{digital}}$

Do we believe that $\text{IE}_{\text{Spur DAS}}$ can be driven down in frequency by a factor of 10 to 100 or that digital systems are one to two orders of magnitude less reliable than comparable analog equipment?

Is it appropriate to introduce a spurious trip that is relatively likely to occur over the lifetime of the plant to address an initiating event that is not expected to occur over the life of the entire fleet of plants?

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- Risk Insights

- The benefits of providing means of diverse actuation following relatively frequent initiators that have multiple diverse mitigating systems is not disputed.
- The benefits of automatic DAS for the LOCAs is very small (even when considering a spectrum of events that are broader than that required by BTP-19).
- There are competing risks associated with a DAS which, for other regulations directed at addressing CCF, are addressed by limiting the analysis to anticipated operational occurrences (e.g., the ATWS Rule).
- The most significant negative effects are associated with automatic DAS that result in the disabling of mitigating systems should they spuriously actuate (e.g., MSIV closure, Feedwater Isolation).

Risk Insights from PRA Related to D3 ISG on Credit for Operator Action

- What is the reason that the diverse ESFAS provides benefits that are so limited?
 - Frequency of initiating events for which it would be useful is small:
 - LOCAs
 - RCS is designed in accordance with consensus codes and standards (e.g., Section III of ASME B&PV Code)
 - Periodic examination of RCS components is performed in accordance with accepted codes and standards (e.g., Section XI of ASME B&PV Code)
 - Frequent monitoring of the integrity of the RCS is performed and corrective action is taken when predefined limits are exceeded (e.g., leakage detection systems)
 - Reliability of ESFAS is high
 - Quality software life cycle processes
 - Functional diversity
 - Self testing, data validation, fault tolerance, procedural restrictions allowing changes to only one channel at a time, operating system 'blind' to plant transients, constant loading of communication and processing buses,...

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- Consistency with the Principles of Risk Informed Regulation
 - Meet existing regulations or justify exemption
 - Maintain safety margin
 - **Consistency with defense-in-depth philosophy**
 - Assure a low change in CDF and LERF
 - Monitor performance of the change following implementation

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- **Consistency with defense-in-depth philosophy**
 - How is defense against common cause failures provided without diverse actuation?

The ESFAS can be designed such that there is little potential for CCF between the causes of Large LOCAs/SLBs as initiating events and the ESFAS.

- A source of diversity that is not required by BTP-19 for any initiating event including the much more frequent Anticipated Operational Occurrences (Turbine Trip, Loss of Feedwater,...)

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- Conclusions

- Even if there were no negative effects associated with a DAS directed at limiting credit for operator action (i.e., a DAS could be designed that will not result in reactor trip should it spuriously actuate), there is insufficient value-impact to justify a requirement for an automatic DAS during rare events.

This is a result of

- Meeting existing codes and standards for the design and inspection of the RCS
- Designing, installing and maintaining a highly dependable ESFAS that meets accepted design processes and has defensive measures that limit the potential for CCF
- Assuring that the cause of the initiators for which the DAS may be of benefit and the ESFAS have low potential for CCF.
- There appears to be a small but negative effect associated with providing automated diverse actuation systems (DAS) for some accident initiators.

This is a result of the competing risks of addressing failure of mitigating system actuation for rare events vs. the creation of new, more frequent transients resulting from spurious operation of the DAS.

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- The ISG should be modified to limit the scope of D3 evaluations to anticipated transients, and remove the inconsistency with other regulations directed at addressing the effects of CCF, such as the ATWS Rule.

Otherwise, there is no clear evidence that the resulting automatic DAS will not introduce as much risk as it addresses.