Common Cause Failure Analysis

Lecturer

Lesson IV 3_7.2

Workshop Information

IAEA Workshop

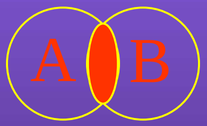
City, Country
XX - XX Month, Year

Dependent Failures

Independent Events

$$P\,(A\ \&\ B) = P\,(A) \cdot P\,(B)$$

Dependent Events



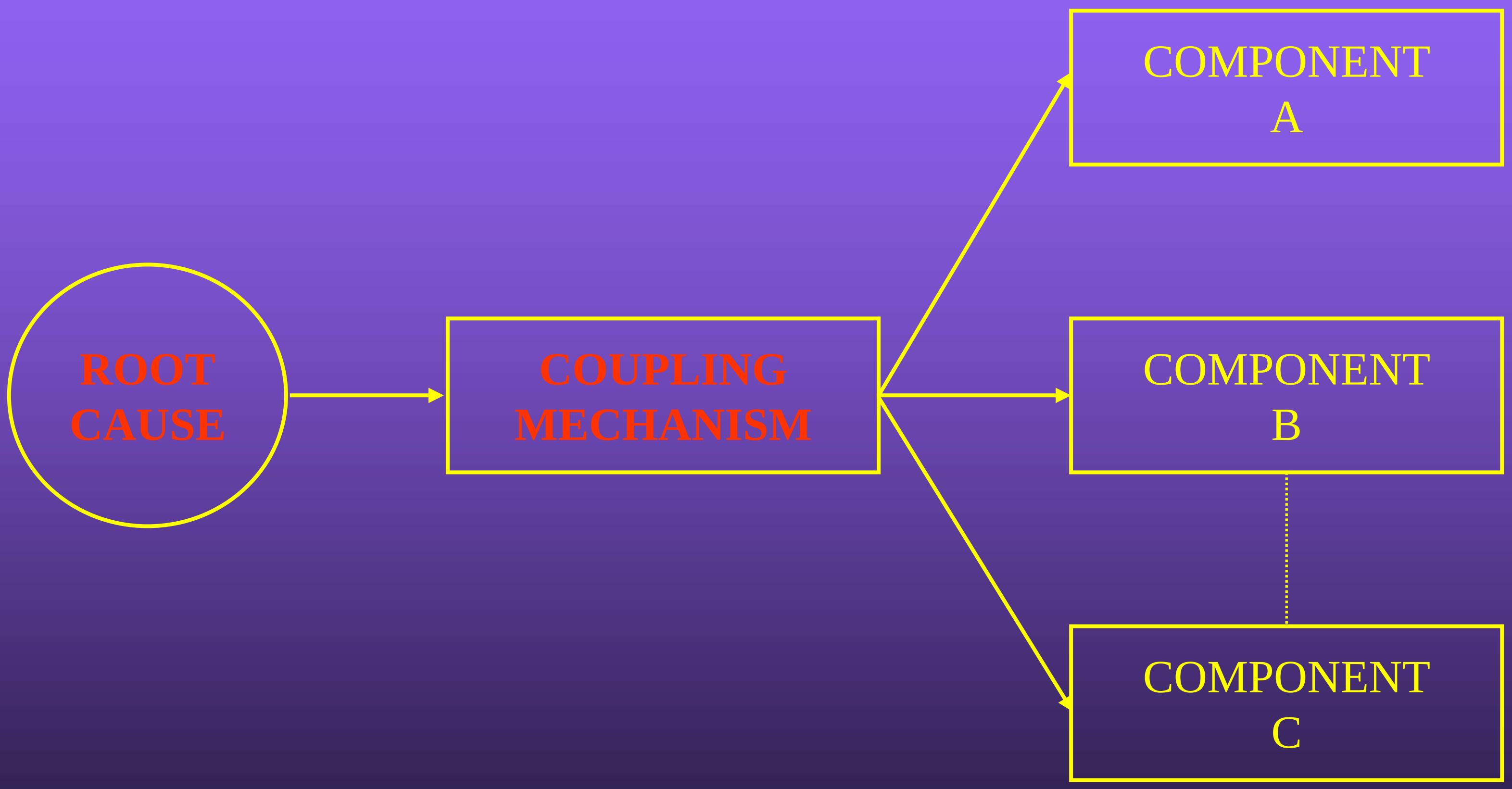
$$P\,(A\ \&\ B) > P\,(A) \cdot P\,(B)$$

$$P\,(A\ \&\ B) = P\,(A) \cdot P\,(B/A)$$

Types of Dependent Events Based on Their Impact on a PSA Model

Dependent Event Type	Characteristics	Subtypes (coupling mechanisms)	Examples (trigger events)
1. Common Cause Initiating Event	Causes a plant transient and increases unavailability of one or more mitigating systems.	• Functional • Spatial • Human	• Loss of offsite power. • Earthquake. • Maintenance error shorting out instrument bus.
2. Intersystem Dependency	Causes a dependency in a joint event probability involving two or more systems.	• Functional • Spatial • Human	• Coolant charging fails because component cooling fails. • Fire causes loss of equipment of two systems. • Operator error causes loss of two systems.
3. Intercomponent (intrasystems) Dependency	Causes a dependency in a joint event probability involving two or more components.	• Functional • Spatial • Human	• Battery loses charge after it is run beyond capacity. • Fire causes loss of redundant pumps. • Design error present in redundant pump controls.

Physical Elements of a Dependent Event



Dependent Failures

ROOT CAUSE

- Hardware
- Human
- Environmental
- External to the Plant

COUPLING MECHANISM

- Functional Coupling
  - Connected equipment
  - Nonconnected equipment
- Spatial Couplings
  - Spatial proximity
  - Linked equipment
- Human Couplings

Common Cause Failures

DEFINITION

- Subset of Dependent Failures in which two or more component fault states exist at the same time, or within a short time interval, as a result of a shared cause.
- The shared cause is not another component state because such cascading of component states, due to functional couplings, are already usually modelled explicitly in system models.
- Residual dependent failures whose root causes are not explicitly modeled in the PSA.

SIGNIFICANCE

- Defeat the redundancy employed to improve the reliability of safety functions.
- Operating experience has shown that CCF are major contributors to plant risk.

General Insights Regarding CCF Events

- Programmatic maintenance practices, major contributors.
- Design problems, specially those resulting from design modifications.
- Human errors, small percentage but greater impact.
- Testing and surveillance program, prevention of CCF.
- Plant-to-plant variability.

CCF Models Characteristics (1/2)

- Basic Parameter:
  - Q_k can be calculated directly from data.
  - Data required are not normally available, so other models with less stringent requirements on data are used.
- Beta Factor:
  - Do not need component success data.
  - Simplicity is its main advantage
  - Provides conservative results for redundancy levels beyond two (2).

CCF Models Characteristics (2/2)

- Multiple Parameter Models:
  - More appropiate for systems with higher levels of redundancy..
  - Alpha-factor parameters are more simple to obtain from observable events than MGL.
- BFR Model:
  - Component subject to independent failures and dependent shocks (lethal and non-lethal).
  - Uses two parameters.
  - Less conservative results than β - factor for higher redundancy levels.
  - More restrictive than all other multiparameter models.

CCF Data Collection

- CCF are rare events.
- Individual plants present limited experience.
- Global industry experience is needed to make statistical inferences.
- There is a significant variability among plants due to differences in coupling mechanisms and defences.
- Careful review and screening of events with the plant design and the PSA models, to ensure consistency of the data base, is convenient to reduce uncertainties.

Key Characteristics of Parametric Models for CCF Quantification

ESTIMATION APPROACH			MODEL	MODEL PARAMETERS*	GENERAL FORM FOR MULTIPLE COMPONENT FAILURE FREQUENCY
NONSHOCK MODELS	DIRECT		BASIC PARAMETER	$Q_1, Q_2, \ldots, Q_m$	$Q_k = Q_k \quad k = 1, 2, \ldots, m$
NONSHOCK MODELS	INDIRECT	SINGLE PARAMETER	BETA FACTOR	Q_t, β	$Q_k = \begin{cases} (1-\beta) Q_t & k = 1 \\ 0 & m > k > 1 \\ \beta Q_t & k = m \end{cases}$
NONSHOCK MODELS	INDIRECT	MULTIPARAMETER	MULTIPLE GREEK LETTERS	$Q_t, \underbrace{\beta, \gamma, \delta, \ldots}$ m − 1 PARAMETERS	$Q_k = \frac{1}{\binom{m-1}{k-1}} \left(\prod_{i=1}^{k} \rho_i \right) (1 - \rho_{k+1}) Q_t$ $\rho_1 = 1, \rho_2 = \beta, \rho_3 = \gamma, \ldots, \rho_{m+1} = 0$
NONSHOCK MODELS	INDIRECT	MULTIPARAMETER	ALPHA FACTOR	$Q_t, \alpha_1, \alpha_2, \ldots, \alpha_m$	$Q_k = \frac{k}{\binom{m-1}{k-1}} \frac{\alpha_k}{\alpha_t} Q_t \quad k = 1, \ldots, m$ $\alpha_t \equiv \sum_{k=1}^{m} k \alpha_k$
SHOCK MODELS			BINOMIAL FAILURE RATE	Q_I, μ, ρ, w	$Q_k = \begin{cases} \mu \rho^k (1-\rho)^{m-k} & k \neq m \\ \mu \rho^m + w & k = m \end{cases}$

CCF Event Classification and Analysis Summary

Component	Reactor Years	Number of Events Classified	Event Distribution					Generic Beta Factor
			Independent	Dependent	Generic Common Cause Events			
					Potential	Actual		
Reactor Trip Breakers	563	72	56	16	3	8		.19
Diesel Generators	394	674	639	35	9	13		.05
Motor-Operated Valves	394	947	842	105	17	25		.08
Safety/Relief Valves								
PWR	318	54	30	24	0	0		.07
BWR	245	172	136	36	7	7		.22
Check Valves	654	254	242	12	3	5		.06
Pumps								
Safety Injection	394	112	77	35	2	6		.17
RHR	394	117	67	50	2	3		.11
Containment Spray	394	48	32	16	1	1		.05
Auxiliary Feedwater	394	255	194	61	2	3		.03
Service Water	394	203	159	44	2	2		.03
Chillers	654	33	27	6	2	2		.11
Fans	654	59	49	10	2	3		.13
All	-	3,000	2,550	450	52	78		.10[c]