Common Cause Failures and Cascading Failures

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Background

- Complex systems
  - Advanced and digitalized functions
  - Interactions and dependency

- Dependent failures
  - Common cause failure (CCF)
  - Cascading failures

- Objectives:
  - Similarities
  - Differences
  - Barriers
Why is it important

• To understand phenomena and mechanisms of the failures:
  – CCF: Main contributors of the failures in safety critical systems (oil & gas)
  – Cascading failures: fires (chemical), blackouts (power), conflicts (railway)

• To help making decisions on barrier strategies:
  – Barriers against CCFs V.S. Barriers against cascading failures
CCFs

Definitions
- Two or more component faults
- Exist simultaneously or in a short time interval
- A shared cause

Explanation
- Root causes: most basic reason for the component failure
- Coupling factors: characteristic of components with same causal mechanisms

At least two failures are due to a shared or common cause

Ref: TPK5170 course note
Ref: PDS Report

Models
- Direct estimate models
- Ratio models
- Shock models
Cascading failures

Definitions

- Multiple failures initiated by the failure of one component
- Result in a chain reaction
- Affect remaining components

Explanation

- Root causes
- Coupling factors
- Coupling paths

Models

- Topology analysis
- Probabilistic risk assessment
- Optimization of maintenance
- Reliability analysis

Multiple failures may have sequential effects
Similarities

- Multiplicity
- Timeliness
- Root causes

Fig. 1. Comparison of CCFs and cascading failures
Differences

- Initiation
- Propagation
- Consequence

Fig. 1. Comparison of CCFs and cascading failures
Barriers

- Barriers for both failures
- Barriers for CCFs
- Barriers for cascading failures

Fig. 2. Safety barriers against DFs based on bow-tie models
Case study 1

Assumptions:
- CCF: $\beta = 0.1$
- Cascading failures: $p_{12} = 0.1$

Method:
- Analytical formulas

Fig. 3 Two-component system with CCFs and cascading failures

Fig. 4 Effects of CCFs and cascading failures on system reliability
Case study 2

Assumptions

- **CCF**: $\beta=0.1->0$
- **Cascading failures**:
  - B1: $P_{12}=0.3->0$
  - B2: $\lambda_2=0.001->0$
  - B3: $P=0.3->0$

Method:

- Monte Carlo Simulation

Fig. 5 Five-component system with CCFs and cascading failures

Fig. 6 Effects of barrier against CCFs

Fig. 7 Effects of barriers against cascading failures

$\lambda=0.001$/hour
Conclusion and further work

• Answer the questions:
  – Why such dependent failures initiate
  – How dependent failures contribute to disruptions of systems
  – What kinds of barriers are needed and implemented

• Further works:
  – More advanced quantitative analyses are required in a larger and more complex system
  – To perform further barrier analysis for dependent failures
Thanks!