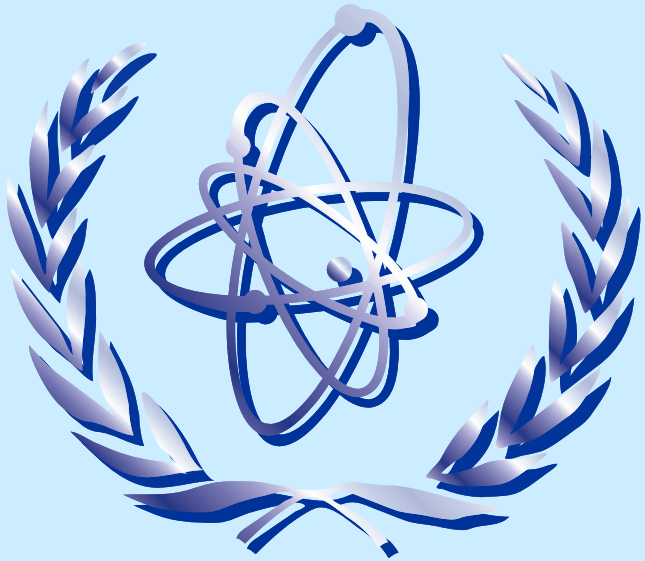
# Basic Level 1. PSA course for analysts



## Reliability data analysis - use of generic and/or plant-specific data

# Content

- Types of data for PSA
- Reliability models
- Data sources
- Use of the different data sources
- Reliability data collection
  - Grouping of components
  - What to collect?
  - Data collection system
  - Data assessment problems

# Types of data for PSA

- Initiating event data
  - Initiating event frequencies
    - $f_{IE}$ *(1/year)*

- PSA basic event data
  - component random failures
  - unavailabilities due to test or maintenance
  - human errors

- probabilities
  - reliability parameters

# Types of data for PSA - Initiating event data

- Frequent events
  - information collected at the plant
    - derive frequency from the number of events occurring over a time period
- Infrequent events
  - System analysis to derive system failure rates
    - e.g. fault tree analysis
  - Expert judgement

# Types of data for PSA - PSA basic event data

- Component random failures
  - Failures Standby components
    - Typically failures of components of safety systems, normally waiting for their mission. Under required conditions they must start and run for the mission period.
    - example failure modes:
      - fail to operate on demand
      - fail to continue running during the mission time
  - Failures of running components
    - Typically failures of components of systems in operation during normal conditions, which must continue running during fault conditions
    - example failure modes:
      - fail to continue running during the mission time

# Types of data for PSA - PSA basic event data (Cont.)

- Test and maintenance unavailabilities
  - Probability not functioning due to being under maintenance, or being under test.
    - depends on plant practice => plant specific estimation!
- Human errors
  - not covered here, presentation later
- Common cause events
  - sometimes handled as basic events based on parametric models, not covered here, presentation later

# Reliability models

## Tested stand-by components

- **Hardware failure probability**

$$1 - \frac{1 - e^{-\lambda_S T}}{\lambda_S T} \approx \frac{\lambda_S T}{2}$$

**where** $\lambda_s$ **is the stand-by failure rate (1/hour), and**

**T is the test period (hour)**

**Data requirements:**

$\lambda_s$ **number of observed failures**

# Reliability models

## Tested stand-by components

- Test outage

$$\frac{\tau}{T} q_0$$

where $\tau$ is average test duration (hour),

T is the test period (hour) and

$q_0$ override unavailability (if applicable)

Data requirements:

$\tau$ observed test durations

# Reliability models

## Tested stand-by components

- **Repair outage**

$$\lambda_S T_R$$

where $\lambda_S$ is the stand-by failure rate (1/hour), and

$T_R$ is main time to repair (hour)

Data requirements:

$\lambda_S$ number of observed failures

$T_R$ observed repair durations

# Reliability models

## Tested stand-by components

- Scheduled maintenance

$$f_m T_m$$

where $f_m$ is the maintenance frequency (1/hour), and

$T_m$ is the average maintenance duration (hour)

Data requirements:

$T_m$ observed maintenance duration

# Reliability models

## Tested stand-by components

- **Untested stand-by component**

$$1 - \frac{1 - e^{-\lambda_S T_p}}{\lambda_S T_p}$$

where $\lambda_s$ is the stand-by failure rate (1/hour), and

$T_p$ is the fault exposure time (hour)

Data requirements:

$\lambda_s$ number of observed failures

$T_p$ component replacement time

# Reliability models

## Tested stand-by components

- Monitored stand-by component

$$\frac{\lambda_S T_R}{1+\lambda_S T_R}$$

where $\lambda_S$ is the stand-by failure rate (1/hour), and

$T_R$ is main time to repair (hour)

Data requirements:

$\lambda_S$ number of observed failures

$T_R$ observed repair durations

# Reliability models

## On-line components

- **Non-repairable component**

$$1 - e^{-\lambda_O T_M}$$

**where** $\lambda_O$ **is the operating failure rate (1/hour), and**

$T_M$ **is PSA mission time (hour)**

**Data requirements:**

$\lambda_O$ **number of observed failures**

# Reliability models

## On-line components

- On-line repairable component

$$\frac{\lambda_O T_R}{1+\lambda_O T_R}$$

where $\lambda_O$ is the operating failure rate (1/hour), and

$T_R$ is main time to repair (hour)

Data requirements:

$\lambda_O$ number of observed failures

$T_R$ observed repair durations

# Data sources

- Statistical data, not probabilistic
- Exact solution:
  - n failures out of N demands:

$$P = \lim_{N \to \infty} \frac{n(N)}{N}$$

- Estimation:

$$P = \frac{n}{N}$$

(the larger N is the better estimation we have)

# Data sources (Cont.)

- Plant specific data
  - plant event records
  - test records
  - maintenance records
  - defect records
  - component reliability data collection
- Data from similar plants
  - type specific data

# Data sources (Cont.)

- Generic data
  - International data bases:

    *IAEA-TECDOC-478 : Component reliability data for use in PSA*

    *European Industry Reliability Databank,*
  - some US references
    - *INITIATING EVENT FREQUENCIES*

      *- NUREG/CR-5750, FEBRUARY 1999*
    - *LOSS OF OFFSITE POWER*

      *- NUREG/CR-5496, NOVEMBER 1998*
    - *SPECIFIC SYSTEMS (RPS, AFW, OTHERS)*

      *- NUREG/CR-5500, CONTINUING*

# Use of the different data sources

- Plant data should be most appropriate
  - often not available in usable form
- If plant data not available, use data from similar plant
- If no suitable data available, select generic databases that are relevant to the plant type (taking into account any plant features) and use expert judgement to select the most appropriate data (What we expect from the component behaviour in the future?)

# Grouping of components

**GOALS OF GROUPING**

- INCREASE OF STATISTICAL SIGNIFICANCE REDUCTION EFFORTS FOR COLLECTION AND PROCESSING
- STREAMLINED INTEGRATION WITH PSA MODELS

**ADVANTAGES**

- ⇨ BROADER BASIS, INCREASED SIGNIFICANCE OF POPULATION
- ⇨ SIMPLIFIED DATA COLLECTION AND DB DESIGN

**DRAWBACKS**

- ⇨ MASKING TRENDS AND PECULIARITIES
- ⇨ MEANINGLESS AVERAGES

# Grouping of components

## Guidance on grouping - PUMPS

**ACCEPTABLE GROUPING**

- MOTOR CENTRIFUGAL PUMPS (VERTICAL; HORIZONTAL)
- RHR, CS AND SI; CW AND SW; CVCS AND HPSI

**GROUPING DISCOURAGED**

- CENTRIFUGAL AND PDPS; MOTOR AND TURBINE
- REACTOR AND COOLING WATER
- MFW AND AFW (EFW)
- SCREEN WASH AND SW
- RHR AND CONDENSATE

# Grouping of components

## Guidance on grouping - BREAKERS

**ACCEPTABLE GROUPING**

- SIMILAR DESIGN AND VOLTAGE LEVEL
- SIMILAR FREQUENCY OF OPERATION
- SIMILAR MAINTENANCE/TESTING FREQUENCY

**GROUPING DISCOURAGED**

- FREQUENTLY VS. NON-FREQUENTLY OPERATED
- DIFFERENT DESIGN, VOLTAGE LEVEL (HV LESS RELIABLE)
- CIRCUIT BREAKERS AND DISCONNECTS
- POWER BREAKERS AND SWITCHES

# Grouping of components

## Guidance on grouping - TRANSDUCERS

**ACCEPTABLE GROUPING**

- ALL TRANSDUCERS FOR SIMILAR MEASUREMENT
- THE APPLICATION OR ENVIRONMENT MATER LITTLE

**GROUPING DISCOURAGED**

- INSTRUMENTS OF DIFFERENT DESIGN
- DIFFERENT MEASUREMENT
- DIFFERENT MANUFACTURER (case by case)

# What to collect?

**DATA NEEDS:**

**FOR FAILURE RATES**

- **NUMBER OF FAILURES OVER TIME**
  - **n, Texp**
- **NUMBER OF FAILURES ON DEMAND**
  - **n, Ndem**

**FOR TEST UNAVAILABILITIES**

- **test frequency, test duration**

**FOR MAINTENANCE UNAVAILABILITIES**

- **frequency and duration of planned maintenance,**
- **number and duration of corrective maintenance**

# Data collection system

Data collection possibilities:

"One shot" task

analysis of the past experience investigating maintenance, test records, operator logbooks, etc. in order to estimate the PSA parameters.

-> sometimes the available information is not complete, and results in optimistic estimations

Establish component reliability data collection system, consisting of:

personnel responsible for data collection

computerised database to record the data, and perform data assessment and calculation of PSA parameters and uncertainties

Establish multipurpose reliability data collection system

# Data assessment problems

**Use of test records:**

**Standby components may only be tested for short periods, not long enough to provide good statistical data. There is a danger that the data will be too pessimistic. It may therefore be necessary to use generic data until sufficient site data has been gathered. Sometimes, the testing regime will never enable sufficient running hours to be established consideration of a change to the test regime may be beneficial.**

# Data assessment problems (Cont.)

**EQUIPMENT CHARACTERISTICS SHOULD BE CONSISTENT WITH PSA MODELS**

- LEVEL OF DETAIL
- COMPONENT BOUNDARIES
- DEFINITION OF FAILURE

**Sometimes it is difficult to reach**

# References

- IAEA-TECDOC-478 Component reliability data for use in probabilistic safety assessment (1988)
- IAEA-TECDOC-508 Survey of ranges of Component reliability data for use in probabilistic safety assessment (1989)