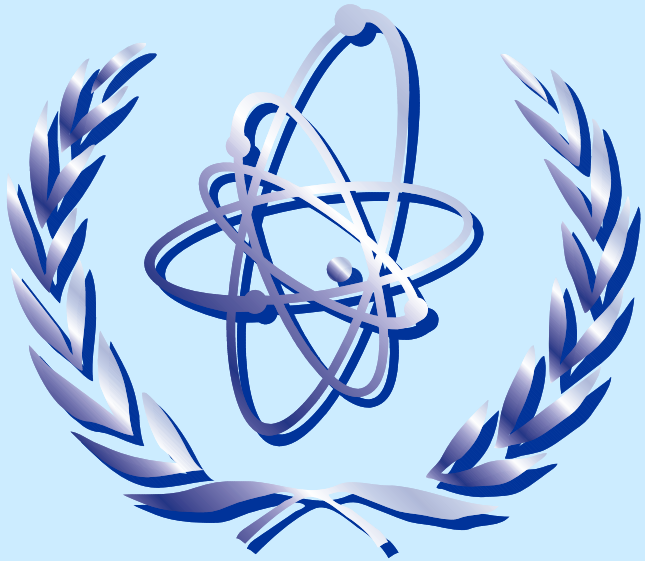
Basic Level 1. PSA course for analysts



Initiating Event Analysis

Content

- Initiating event selection and grouping
- Numerical screening of initiating events
- Transients and LOCAs
- Support system initiating events

DEFINITION OF INITIATING EVENTS

- **Definition:**
  - **"An initiating event is an event that creates a disturbance in the plant and has a potential to lead to core damage, depending on the successful operation of the various mitigating systems of the plant." (IAEA Safety Series No. 50-P-4)**

GROUPING OF INITIATING EVENTS

- Selection of initiating events based on:
  - Scope of the PSA
    - Operating mode to be modelled
      - Full power
      - Shutdown and low power
    - Initiating event category
      - Internal initiating events
      - internal and external hazards

GROUPING OF INITIATING EVENTS

- Selection methods
  - Engineering evaluation
  - Reference to previous lists
  - Deductive analysis
  - Operational experience

GROUPING OF INITIATING EVENTS

- PLANT RESPONSE
- SUCCESS CRITERIA
- SUPPORT SYSTEMS
- OPERATOR ACTIONS
- LEVEL 2 IMPACTS

NUMERICAL SCREENING

- MOST PSAs INCLUDE FAIRLY "STANDARD" SET OF INITIATING EVENTS FROM FRONTLINE SYSTEM FAILURES (TRANSIENTS, LOCAs, ETC.)
- NUMERICAL ARGUMENTS TYPICALLY USED TO LIMIT SCOPE OF SUPPORT SYSTEM INITIATING EVENTS AND EXTERNAL INITIATING EVENTS
- NUMERICAL CRITERIA ARE OFTEN NOT JUSTIFIED OR ARE NOT CONSISTENT WITH QUANTIFICATION OF OTHER PSA INITIATING EVENTS
- MAJOR PROBLEM IN SOME REVIEWS

NUMERICAL SCREENING

- CANNOT BE JUSTIFIED ONLY BY ESTIMATED INITIATING EVENT FREQUENCY
- MUST CONSIDER RISK CONSEQUENCES
  - LEVEL 1 MODELS / SUCCESS CRITERIA
  - OPERATOR ACTIONS
  - LEVEL 2 CONSEQUENCES
- RISK CONTRIBUTORS
  - HIGH FREQUENCY / LOW CONSEQUENCES
  - MEDIUM FREQUENCY / MEDIUM CONSEQUENCES
  - LOW FREQUENCY / HIGH CONSEQUENCES

NUMERICAL SCREENING
LIVING PSA

- IMPROVED MODELS AND RESULTS
  - REFINED THERMAL / HYDRAULIC ANALYSES
  - REFINED SUCCESS CRITERIA
  - OPERATOR RECOVERY ACTIONS
  - IMPROVED DATA
- SCREENING BASED ON PRELIMINARY MODELS / RESULTS OFTEN NOT VALID FOR FINAL MODELS / RESULTS
- MUST CONSISTENTLY REEVALUATE SCREENING CRITERIA AFTER EVERY PSA UPDATE

NUMERICAL SCREENING

** GENERAL RULE **

- QUANTIFY THE INITIATING EVENT
- LET THE PSA MODELS CONFIRM ITS ACTUAL SIGNIFICANCE

CONSEQUENTIAL IMPACTS

- INITIATING EVENT STARTS SERIES OF POSSIBLE RESPONSES
  - EQUIPMENT SUCCESSES / FAILURES
  - OPERATOR ACTIONS
- DO NOT COMBINE INITIATOR AND CONSEQUENCES
- THE FOLLOWING CONSEQUENTIAL CONDITIONS ARE NOT INITIATING EVENTS
  - STATION BLACKOUT
  - ATWS
  - OVERCOOLING

TRANSIENTS AND LOCAS

- TOO MUCH EMPHASIS ON LOCAS
  - SIZE, LOCATION, FREQUENCY
  - COMPLEX SUCCESS CRITERIA
- TOO LITTLE EMPHASIS ON TRANSIENTS
  - BROAD INITIATING EVENT GROUPS
  - TREATMENT OF TRANSIENT-INDUCED IMPACTS
  - SCOPE OF SUPPORT SYSTEM INITIATING EVENTS
- FULL-SCOPE LEVEL 1 PSA RESULTS TYPICALLY DOMINATED BY TRANSIENTS AND SUPPORT SYSTEM FAILURES

TRANSIENT-INDUCED IMPACTS

- PRIMARY OVERPRESSURE
- SECONDARY OVERPRESSURE
- OVERCOOLING
- ATWS
- MAKEUP / LETDOWN
- REACTOR COOLANT PUMP SEAL FAILURE
- ENVIRONMENTAL / PHYSICAL DAMAGE
- CONTAINMENT

SUPPORT SYSTEM INITIATING EVENTS

- "PARTIAL" SYSTEM FAILURES
- OPERATOR ACTIONS / RECOVERY
- OFFSITE POWER
- VENTILATION / ROOM COOLING

SUPPORT SYSTEM INITIATING EVENTS

- GENERIC DATA NOT DIRECTLY RELEVANT
- GENERIC EXPERIENCE USEFUL FOR "SANITY CHECK"
- DEVELOP PLANT-SPECIFIC MODELS
- ACCOUNT FOR OPERATOR ACTIONS

OPERATOR ACTION DEPENDENCIES

- MUST ACCOUNT FOR DEPENDENCIES WITH OPERATOR ACTIONS IN INITIATING EVENT MODELS
- QUANTIFY SEPARATE INITIATING EVENTS
- INITIATING EVENT CAUSED BY ONLY HARDWARE FAILURES
  - NO PRECEDING ERROR DEPENDENCE
- INITIATING EVENT CAUSED BY COMBINATION OF HARDWARE FAILURES AND OPERATOR ERRORS
  - DEPENDENCE ON PRECEDING ERRORS
  - DIFFERENT POST-INITIATOR ERROR RATES

"PARTIAL" SYSTEM FAILURES

- HIGHER FREQUENCY THAN TOTAL FAILURE
- CONDITIONAL CORE DAMAGE FREQUENCY MAY BE HIGH
- ACCOUNT FOR ASYMMETRIES IN PLANT DESIGN

"PARTIAL" SYSTEM FAILURES

- ONE AC BUS
- ONE DC BUS
- OFFSITE POWER TRANSFORMERS
- ONE TRAIN OF COOLING WATER
- ONE TRAIN OF VENTILATION

ONSITE ELECTRIC POWER FAILURES

- IMPACTS ON PLANT RESPONSE
  - "SAFETY-RELATED" BUSES
  - "NON-SAFETY" BUSES
- IMPACTS ON POWER RECOVERY
  - POWER SUPPLY TO BUS
  - TRANSFORMER FAILURE
  - BUSWORK FAILURE

PRECURSOR EVENTS

- CONDITIONS THAT REQUIRE RAPID AUTOMATIC OR MANUAL POWER REDUCTION (MORE THAN ~30 % POWER)
- AUTOMATIC / MANUAL PLANT RUNBACK
- PLANT-SPECIFIC MODEL FOR INITIATING EVENT FREQUENCY

PLANT RUNBACK MODELS

- SUCCESSFUL RUNBACK
  - PLANT STABILIZED AT REDUCED POWER
  - NO PSA INITIATING EVENT
- RUNBACK FAILURE
  - PLANT TRIP
  - PSA INITIATING EVENT
  - MAY BE GROUPED WITH OTHER SIMILAR INITIATORS

PLANT RUNBACK MODELS / DATA

- AVOID DETAILED MODELS FOR RUNBACK LOGIC / SIGNALS / CIRCUITS
- DERIVE FAILURE RATES FROM OBSERVED EXPERIENCE
  - RELIABILITY OF RUNBACK FUNCTION
  - ACTUAL EXPERIENCE USUALLY WORSE THAN MODEL PREDICTIONS
  - CATEGORIES OF RUNBACK CHALLENGES

LOSS OF OFFSITE POWER

- OFFSITE POWER RECOVERY CURVE
- ELECTRIC POWER RECOVERY TIME WINDOWS
- INITIATING EVENT FREQUENCIES
- PSA MODEL IMPACTS

OFFSITE POWER RECOVERY CURVES

- AVOID DETAILED LOGIC MODELS FOR TRANSMISSION LINES, GRID CONNECTIONS, SWITCHYARD
- DETAILED MODELS TYPICALLY OPTIMISTIC, COMPARED WITH ACTUAL EXPERIENCE
- PLANT-SPECIFIC EXPERIENCE TYPICALLY VERY LIMITED
- DERIVE CURVES FROM REGIONAL TRANSMISSION LINE DATA
- USE GENERIC EXPERIENCE FOR "SANITY CHECK"

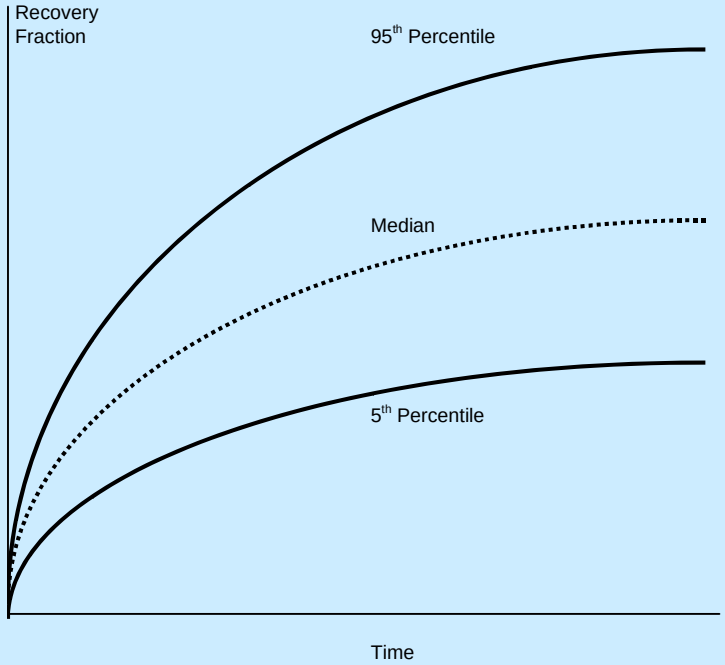
OFFSITE POWER RECOVERY CURVES

- SIMPLIFIED MODEL FROM REGIONAL TRANSMISSION LINE DATA
- FORCED OUTAGES
- OMIT DURATIONS LESS THAN ~1 MINUTE
- TRANSMISSION LINE CORRIDORS
  - VOLTAGES AND ROUTING NEAR PLANT
  - COMMON RIGHT-OF-WAY
  - SIMILAR DIRECTIONAL ROUTING

OFFSITE POWER RECOVERY CURVES

- MODEL EACH CORRIDOR AS A SINGLE LINE
- DERIVE UPPER BOUND CURVE FROM "N" INDEPENDENT CORRIDORS
  - 95TH PERCENTILE RECOVERY
  - CONSERVATIVE IF TRUE INDEPENDENCE APPLIES
- DERIVE LOWER BOUND CURVE FROM FULL CORRELATION OF ALL CORRIDORS
  - 5TH PERCENTILE RECOVERY
  - ACCOUNTS FOR REGIONAL / GRID IMPACTS

OFFSITE POWER RECOVERY CURVES



ELECTRIC POWER RECOVERY TIME WINDOWS

- DC BATTERY LIFE
- PLANT THERMAL / HYDRAULIC RESPONSE
  - STEAM GENERATOR DRYOUT
  - CORE UNCOVERY
- PSA SCENARIOS / SUCCESS CRITERIA
  - REACTOR COOLANT PUMP SEAL FAILURE
  - BLEED-AND-FEED COOLING
  - HIGH PRESSURE / LOW PRESSURE INJECTION
  - CONTAINMENT COOLING

LOSS OF OFFSITE POWER INITIATING EVENTS

- SUBDIVIDE TOTAL FREQUENCY BY EVENT DURATION
  - LESS THAN 30 MINUTES
  - 30 MINUTES - 1 HOUR
  - 1 HOUR - 2 HOURS
  - MORE THAN 2 HOURS
- PSA MODEL IMPACTS
  - DIESEL GENERATOR OPERATING MISSION TIMES
  - AVAILABLE SYSTEMS
  - OPERATOR ACTIONS
- HOUSE EVENTS IN FAULT TREES

LOSS OF VENTILATION / ROOM COOLING

- USUALLY MOST IMPORTANT FOR ELECTRICAL / ELECTRONICS EQUIPMENT
  - SWITCHGEAR ROOMS
  - CONTROL / LOGIC CABINET ROOMS
  - MAIN CONTROL ROOM
- MECHANICAL EQUIPMENT IN SMALL ENCLOSED ROOMS
- VERY IMPORTANT FOR SOLID-STATE EQUIPMENT
  - ENCLOSED CABINETS
  - ENCLOSED ROOMS FOR FIRE / FLOODING
  - UPGRADE / BACKFIT DESIGNS

LOSS OF VENTILATION / ROOM COOLING

- ROOM HEATUP ANALYSES
- EQUIPMENT THERMAL FRAGILITY ANALYSES
- RECOVERY TIME WINDOWS
- RECOVERY SUCCESS CRITERIA
- PSA MODEL IMPACTS

ROOM HEATUP ANALYSES

- REALISTIC ANALYSES OFTEN NOT AVAILABLE
- DESIGN-BASIS CALCULATIONS
  - CONSERVATIVE HEAT LOADS
  - ASSUMPTIONS ABOUT RECOVERY
- PSA MODELS REQUIRE TEMPERATURE VS. TIME AFTER LOSS OF VENTILATION
- SIMPLIFIED CALCULATIONS PROVIDE REASONABLE ESTIMATES
- ACTUAL TESTS

EQUIPMENT THERMAL FRAGILITY ANALYSES

- FAILURE LIKELIHOOD AS A FUNCTION OF TEMPERATURE
- TYPICALLY NOT AVAILABLE FROM MANUFACTURER
- POSSIBLE INFORMATION
  - QUALIFICATION TEMPERATURE
  - RATED OPERATING TEMPERATURE
  - MAXIMUM PERMISSIBLE OPERATING TEMPERATURE
- CONSTRUCT FRAGILITY CURVES FROM AVAILABLE INFORMATION

VENTILATION RECOVERY SUCCESS CRITERIA

- EXTENSION OF ROOM HEATUP ANALYSES
- RECOVERY OPTIONS
  - OPEN DOORS
  - PORTABLE FANS
  - ALTERNATE CHILLED WATER / FORCED COOLING
- SIMPLE LOCAL ACTIONS MAY NOT BE ADEQUATE IF ALL COOLING IS FAILED FOR THE WHOLE BUILDING

VENTILATION RECOVERY TIME WINDOWS

- PROBABILITY DISTRIBUTION FOR TIME UNTIL EQUIPMENT FAILURE
  - ROOM HEATUP CURVES
  - EQUIPMENT THERMAL FRAGILITY CURVES
- TIME WINDOWS FOR OPERATOR ACTIONS
- SEQUENTIAL IMPACTS AS ROOMS HEAT UP
  - PSA EQUIPMENT
  - 0PERATOR ACTION DEPENDENCIES

References

- IAEA-Safety Series 50-P-4 Procedures for Conducting Probabilistic Safety Assessments of Nuclear Power Plants (Level 1)
- IAEA-TECDOC-719 Defining initiating events for the purposes of probabilistic safety assessment
- IAEA-TECDOC-749 Generic initiating events for PSA for WWER reactors
- IAEA-TECDOC-1144 Probabilistic safety assessments of nuclear power plants for low power and shutdown modes