Reliability and Autonomy of ABWR Safety Functions

INPRO Dialogue Forum

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ABWR Operational Response

INPRO Criteria Evaluated:

- CR 1.2.2  Grace Period (Normal Operation)
  - IN 1.2.2  Grace period until human actions are required
- CR 1.3.2  Grace Period (Design Basis Accident)
  - IN 1.3.2  Grace period until human intervention is necessary
- CR 1.3.3  Safety Features
  - IN 1.3.3  Reliability of Engineered Safety Features
- CR 1.3.1  Frequency of DBA
  - IN 1.3.1  Calculated frequency of occurrence of design basis accidents
- CR 1.6.1  Independence of DID Levels
  - IN 1.6.1  Independence of different levels of DID
IN 1.2.2 Grace period until human actions are required

AL 1.2.2 Superior to existing designs in at least some of the aspects discussed in the text.

ABWR Design Features

- Turbine Island
  - Triplicated Fault Tolerant Digital I&C
    - Turbine Control (Steam Bypass and Pressure Control)
    - 3-element Feedwater Level Control
  - Condensate Pumps are 3 x 50% for pumps
  - Feedwater Pumps are 3 x 65%
  - Condensate and Feedwater is N+1 for demineralizers
  - Standby condensate and feedwater pumps auto start if needed
CR 1.2.2 Grace Period (continued)

Nuclear Island

- **Support Systems are arranged in 3 x 100% configuration**
  - Systems in standby are available to auto start in the event that the system running is disrupted
  - Includes On-site safety-related AC power sources
  - Applies to power, cooling (service) water, component cooling water, compressed air, chilled water, Heating Ventilation and Air Conditioning (HVAC), and others
    - Within many systems there are internal redundancies
  - Suppression pool cooling has been automated
    - Prevents inadvertent plant SCRAM on high pool temperature
CR 1.3.2 Grace Period (Design Basis Accidents)

IN 1.3.2 Grace period until human actions are required

AL 1.3.2 Superior to existing designs in at least some of the aspects discussed in the text.

ESBWR Design Features

- Fault Tolerant Digital I&C is designed to execute all actions required for the first 72 hours for transients and DBAs
  - No operator actions are needed in the first 72 hours

- Response to DEC events is also automated
  - Station Blackout is handled by Reactor Core Isolation Cooling (RCIC)
  - Anticipated Transient Without SCRAM (ATWS)
    - Diverse I&C system controls functions
    - Backup actuation of hydraulic scram
    - Alternate insertion of control rods electrically
    - Time delayed actuation of Standby Liquid Control (SLC)
      - Allows chance for electrical run in to complete
CR 1.3.3 Safety Features

IN 1.3.3 Reliability of Engineered Safety Features

AL 1.3.3 Equal or superior to existing designs

ABWR Design Features

Nuclear Island

• Each ESF division has a high and low pressure emergency core cooling (ECC) capability
  • Lessens the probability of having to depressurize the vessel for transients, and small LOCAs

• Removal of residual heat occurs any time a Residual Heat Removal (RHR) division is operated in its many modes
  • Heat exchanger is normally aligned in operation
  • Supporting Systems are also normally in operation

• Interfacing low pressure piping is protected from LOCA
  • Increased design pressure requirements
CR 1.3.3 Safety Features (continued)

- **Elimination of recirculation piping**
  - No large pipe breaks below the core
    - Smaller ECC cooling flow requirements

- **New improved RCIC turbine implemented in latest projects**
  - Water cooled and lubricated
  - Mechanically governed

- **Suppression pool strainer sizing increased**
  - Fibrous insulation material severely limited

- **Available Net Positive Suction Head (NPSH) increased**
  - Pump performance not degraded at elevated suppression pool temperatures
ABWR Emergency Core Cooling System (ECCS)

- **FUNCTION**
  - HIGH PRESSURE CORE FLOODER: AUTO 2
  - REACTOR CORE ISOLATION COOLING: AUTO 1
  - AUTOMATIC DEPRESSURIZATION SYS.: AUTO 2
  - LOW PRESSURE FLOODER: AUTO 3
  - SUPPRESSION POOL COOLING: AUTO 3
  - WETWELL SPRAY: MAN 2
  - DRYWELL SPRAY: MAN 2
  - SHUTDOWN COOLING: MAN 3
  - FUEL POOL COOLING SUPPORT: MAN 2
CR 1.3.1 Frequency of DBA

IN1.3.1 Calculated frequency of occurrence of design basis accidents

AL 1.3.1 Reduced frequency of accidents that can cause plant damage relative to existing facilities

ABWR Design Features

• Fault tolerant digital I&C
  • Safety-related is 2 out of 4 same sensed parameter
  • Other key control systems are triple or dual redundant
  • Lower frequency of I&C initiated transients
  • Human factors principles applied to design operator interfaces

• Safety-related divisions separated
  • Physically by 3-hour fire barriers
  • Electrically
  • Possibility of “hot shorts” is minimized
CR 1.3.1 Frequency of DBA (continued)

- Elimination of more than 30 meter of large pipe below the core
- Enhanced material specifications for stainless steel piping
- Enhanced installation requirements for piping
- Interfacing low pressure piping is protected from LOCA
  - Increased design pressure requirements
- Enhanced pre-service and in-service inspection techniques
  - Better baseline examinations
CR 1.6.1  Independence of DID Levels

IN 1.6.1 Independence of different levels of DID

AL 1.6.1 Adequate independence is demonstrated, e.g., through deterministic and probabilistic means, hazards analysis etc.

ABWR Design Features

• The largest single contributor to core damage in the ABWR PSA is loss of AC power events including Station Blackout
  • Reactor Core Isolation Cooling (RCIC) provides an AC independent means of cooling the core
    • Automatic actuation
    • 8 hours design basis capability
    • Extendable to 24+ hours by reasonable operator actions
  • Air-cooled Combustion Turbine Generator (CTG) provides an Alternate AC capability for addressing loss of AC power events
    • Auto start but manually connected by operators form Main Control Room
    • Can be connected to all key electrical busses
ABWR Key Design Features – Onsite AC Power

CTG

Operational Bus A

Division I

EDG

Operational Bus B

Division II

EDG

Operational Bus C

Division III

EDG
CR 1.6.1 Independence of DID Levels (continued)

• AC Independent Water Addition (ACIWA)
  • Provides an alternate means of injecting water
    • Reactor Pressure Vessel
    • Primary Containment
    • Containment Spray
    • Spent Fuel Pool
  • Utilizes site diesel driven fire pump
    • Water from on-site fire water storage
  • Has connections for fire trucks or portable pumps
AC Independent Water Addition (ACIWA)

Hard piped fire water connections
Seismic Category 1
On-site fire protection system connection
Truck connection
  • Ties to RHR C
References

ABWR

Design Certification Document, Rev. 4: http://www.nrc.gov/reactors/new-reactors/design-cert/abwr.html#dcd


Revision 5 of the ABWR DCD can be found here: http://pbadupws.nrc.gov/docs/ML1100/ML110040323.html

Reference BWR (Grand Gulf NPP) NUREG-1150 http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1150/