US-APWR Mitigation Strategies for BDB External Event

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MHI/MNES

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Acronyms

- AAC : Alternate AC Power Source
- ACC : Accumulator
- AHU : Air handling Unit
- BDB : Beyond Design Base
- CCW : Component Cooling Water
- CHP : Charging Pump
- C/T : Cooling Tower
- DWST : Demineralized Water Storage Tank
- EFW : Emergency Feedwater
- ESW : Essential Service Water
- FSS : Fire protection Water Supply System
- HVAC : Heating, Ventilation and Air Conditioning
- GTG : Gas Turbine Generator
- MCR : Main Control Room
- MSDV : Main Steam Depressurization Valve
- MSSV : Main Steam Safety Valve

Acronyms

- RCP : Reactor Coolant Pump
- RCS : Reactor Coolant System
- RHRS : Residual Heat Removal System
- RWSP : Refueling Water Storage Pit
- RWRP : Refueling Water Recirculation Pump
- SBO : Station Blackout
- SSE : Safe Shutdown Earthquake
- T/D : Turbine Driven
- UHS : Ultimate Heat Sink

Basic US-APWR Strategies

Four phase approach

1. Assessment of event (1hr)

   Evaluation of equipment and systems availability and begin preparations for next phase

2. Coping with installed plant equipment (1 hr - 8 hrs)

   Coping with minimum operator actions from MCR

   Preparation for next phase

3. Coping with installed plant equipment and on-site portable resources (8 hrs – 7 days)

   Coping with both MCR and field operator actions

   Preparation for next phase

4. Coping with both installed plant equipment and off-site resources until power, water, and cooling chain (UHS, ESWS, CCWS) is restored or commissioned, in addition to on-site equipment (after 7 days)

Basis of US-APWR Strategies

I hr after SBO

- By 1 hr, MCR operators evaluate plant conditions and identify the event as SBO

8 hrs after SBO

- By 8 hrs, operators take initial action and prepare preparation for next phase when dc batteries could be depleted and RCP seal integrity could be endangered

7 days after SBO

- By 7 days off-site resources can be available, even for the case of BDE external event

Operational Strategy for Core Cooling after BDB External Event
(Loss of all ac and normal access to UHS)

Phase 1

Phase 1 (0 - 1hr)

- Upon SBO, T/D EFW Pump(s) automatically start for core cooling through SG
  - Water source : EFW Pits
  - Steam release: MSSVs
- Class 1E batteries supply dc power to essential I&C equipment
- RCP No 2 seals maintain integrity
- Operator could assess plant conditions and determine availability of equipment and identify as a SBO event.

Phase 2

Phase 2 (1hr - 8hrs)

- Continue to use T/D EFW Pump(s) for core cooling through SG
  - Water source : EFW Pits
  - Steam release: MSSVs
- After diagnosis, operator sheds unnecessary dc battery loads by turn-on load shedding switches in MCR by 2 hrs. Each switch sheds one of redundant I&C loads and other unnecessary load. See Fig 1
- Class 1E batteries supply dc power to essential I&C equipment at least 8 hrs
- RCP No 2 seals maintain integrity at least 8 hrs

Phase 2

Phase 2 (1hr - 8hrs) Cont

- Preparation for Phase 3
  - Connect AAC(s) to class 1E ac power system
  - Open isolation valves and start two Non-essential Chiller C/T (Non-essential Chiller Cooling Fans and Non-essential Chiller Water System Condenser Water Pumps) to supply cooling water to CHPs, Seal Water Heat Exchanger and to Essential Chiller Units. See Fig. 2
  - Start a CHP to inject cooling water to RCP seals and to makeup borated water to RCS (from RWSP)
  - In addition, FSS can supply cooling water to CHPs, if necessary.

Phase 3

Phase 3 (8hrs – 7 days)

- Use T/D EFW Pump(s), SGs and MSDVs for RCS cooldown
  - Water source : EFW Pits
- Manipulate MSDVs for control of RCS cooldown
- Manipulate EFW flow control valves to maintain SG level
- Manipulate a SDV for RCS pressure control
- Around 11 hr, ACCs automatically initiate water injection for RCS boration and makeup
- When RCS pressure reaches 1.4 MPag (145 psig), isolate ACCs
- By 14 hr, divert the suction of T/D EFW Pump(s) from EFW Pits to DWST, if the tank is available
- If DWST is not available, refill EFW pits with water using an on-site portable water pump from UHS basin by 14 hr

Phase 3

Phase 3 (8hrs – 7 days) Cont

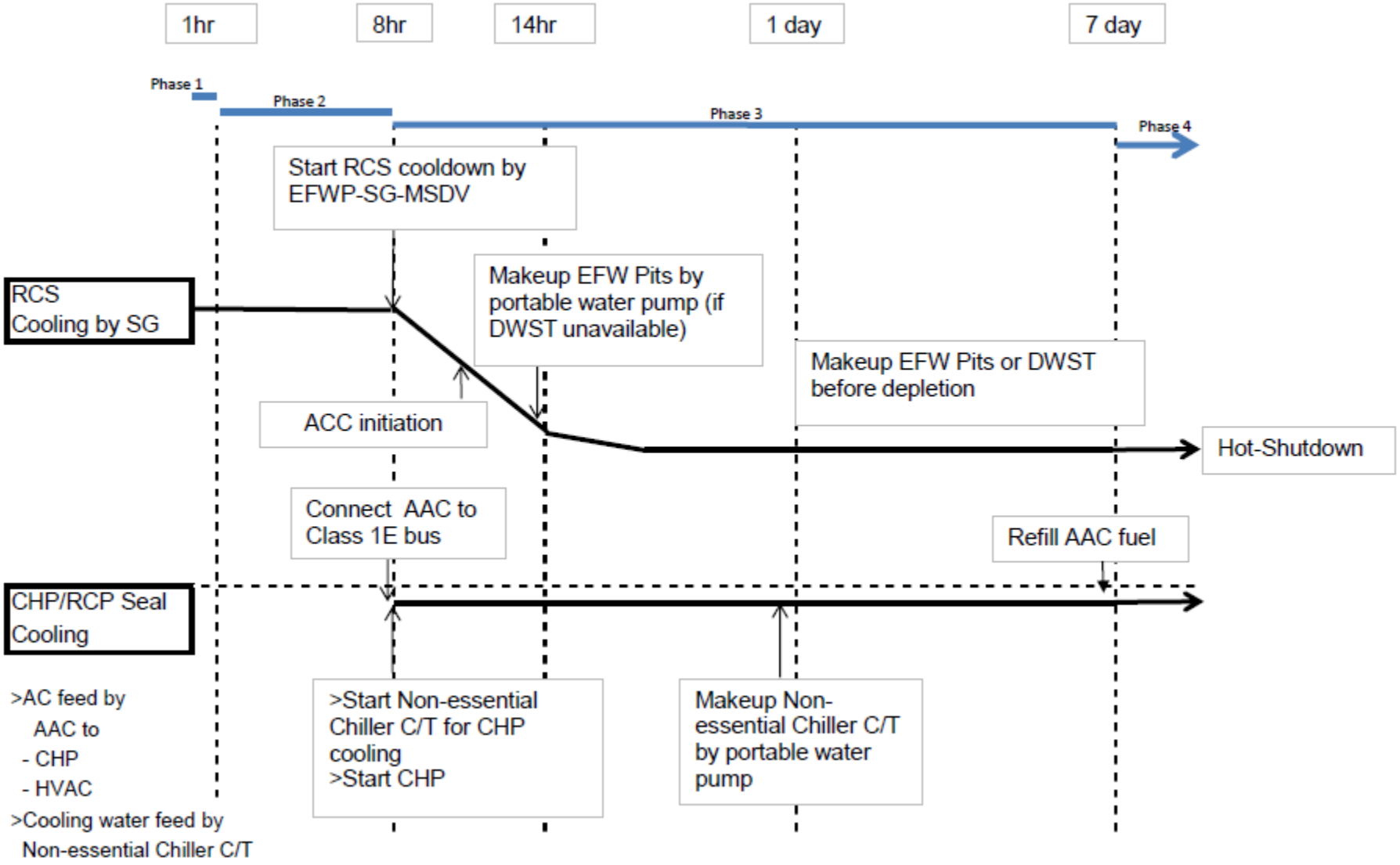
- Start essential HVAC systems (an Essential Chiller Unit Area AHU Fan, a Charging Pump Area AHU Fan, an EFW pump area AHU Fan, a MCR AHU Fan, and a Class 1E Electrical Room AHU Fan)
- Makeup two Non-essential Chiller C/T with water using an on-site portable pump from DWST, if available
- Makeup two Non-essential Chiller C/T with water using an on-site portable pump from UHS basin, if DWST is unavailable
- RCS maintained at Hot Shutdown
- Preparation for Phase 4
  - Refill AAC fuel tank with fuel oil by an on-site or off-site portable equipment

Phase 4

Phase 4 (after 7days)

- Use T/D EFW Pump(s), SGs and MSDVs for RCS cooling
  - Water source : two EFW Pits
- After T/D EFW Pump(s) could not be used, a M/D EFW pump, if available, or a portable pump is used for RCS cooling
- Manipulate MSDVs for control of RCS cooling
- Manipulate EFW flow control valves to maintain SG level
- Manipulate a SDV for RCS pressure control
- Refill EFWS pits with water using a portable pump from UHS basin or off-site portable water source(s)
- Refill Non-essential Chiller C/T with water using a portable pump from UHS basin or off-site portable water source(s)

Core Cooling Timeline



Operational Strategy for SFP Cooling after BDB External Event
(Loss of all ac power and normal access to UHS)

SFP Cooling Phase 1 and Phase 2

Phase 1 (0 - 1hr)

- SFP cooling is monitored.
- Due to large water inventory and low heat generation, no special actions are required

Phase 2 (1hr - 8hrs)

- SFP cooling is monitored
- Due to large water inventory and low heat generation, no special actions are required

SFP Cooling Phase 3

Phase 3 (8hrs – 7 days)

- SFP cooling is monitored.
- Makeup SFP with water in the refueling water storage pit (RWSP) using a refueling water recirculation pump (RWRP: safety-grade)
- Makeup SFP with water using a portable pump from a portable water source or UHS basin via two SFP make-up lines and/or two SFP spray lines when necessary
- If necessary, FSS is used for SFP makeup through the stand pipe on either side of the SFP

SFP Cooling Phase 4

Phase 4 (after 7 days)

- Same as Phase 3

Design Enhancement for Mitigation of BDB External Events

(Loss of all ac and normal access to UHS)

List of Design Enhancement (1/3)

1. **Flood Protection**
   - Enhance protection of essential SSCs from beyond design basis external flood by addition of water-tight doors and penetrations to one floor above the DB flood level of R/B and PS/B
2. **AAC GTG**
   - AAC GTG seismic testing to confirm its operability after a SSE
3. **RCP**
   - Conduct RCP No2 Seal testing for demonstration of the seal performance at least by 8 hrs after SBO through the tests under NQA-1 QA program
4. **dc Power System**
   - Installation of load shedding switches in MCR for Class 1E dc bus. See Fig.1
5. **CHP**
   - Installation of connecting lines from RWSP to CHPs as alternative suction for the pumps, while existing suction lines from SFP to CHPs are eliminated

List of Design Enhancement (2/3)

6. Alternate UHS

- Introducing of alternate UHS : adding connection lines between Non-essential Chiller C/T and 1) CCW piping for CHPs, 2) CCW piping for Seal Water Heat Exchanger, and 3) ESW piping to Essential Chiller Units. See Fig. 2
- Connecting Non-essential Chiller C/T (Non-essential Chiller Cooling Fans and Non-essential Chiller Water System Condenser Water Pumps) to AAC Load Center
- Installation of permanent connection at Auxiliary Building and piping to each Non-essential Chiller Cooling Tower for portable water source
- Seismic analysis of Non-essential Chiller C/Ts to confirm their operability after SSE

List of Design Enhancement (3/3)

7. SFP

- Two sets of wide range and two sets of narrow range safety-related SFP level instrumentations that can monitor (1) level to support operation of the normal fuel pool cooling system, (2) level to provide substantial radiation shielding, and (3) level to confirm water coverage over the spent fuels to implement make-up water addition. See Fig. 2
- Specifications stipulated in the order regarding arrangement, qualification, accuracy and display are also applied
- Elevate seismic category of SFP makeup lines and spray lines to category I

8. EFWS

- Installation of permanent connection at outside of the Reactor Building and piping to each EFW pit for a portable water source
- Installation of automatic opening logic for opening of EFWS Header Tie-line Valves and automatic logic to stop T/D EFWP Emergency Oil Pump

dc Load Shedding Scheme

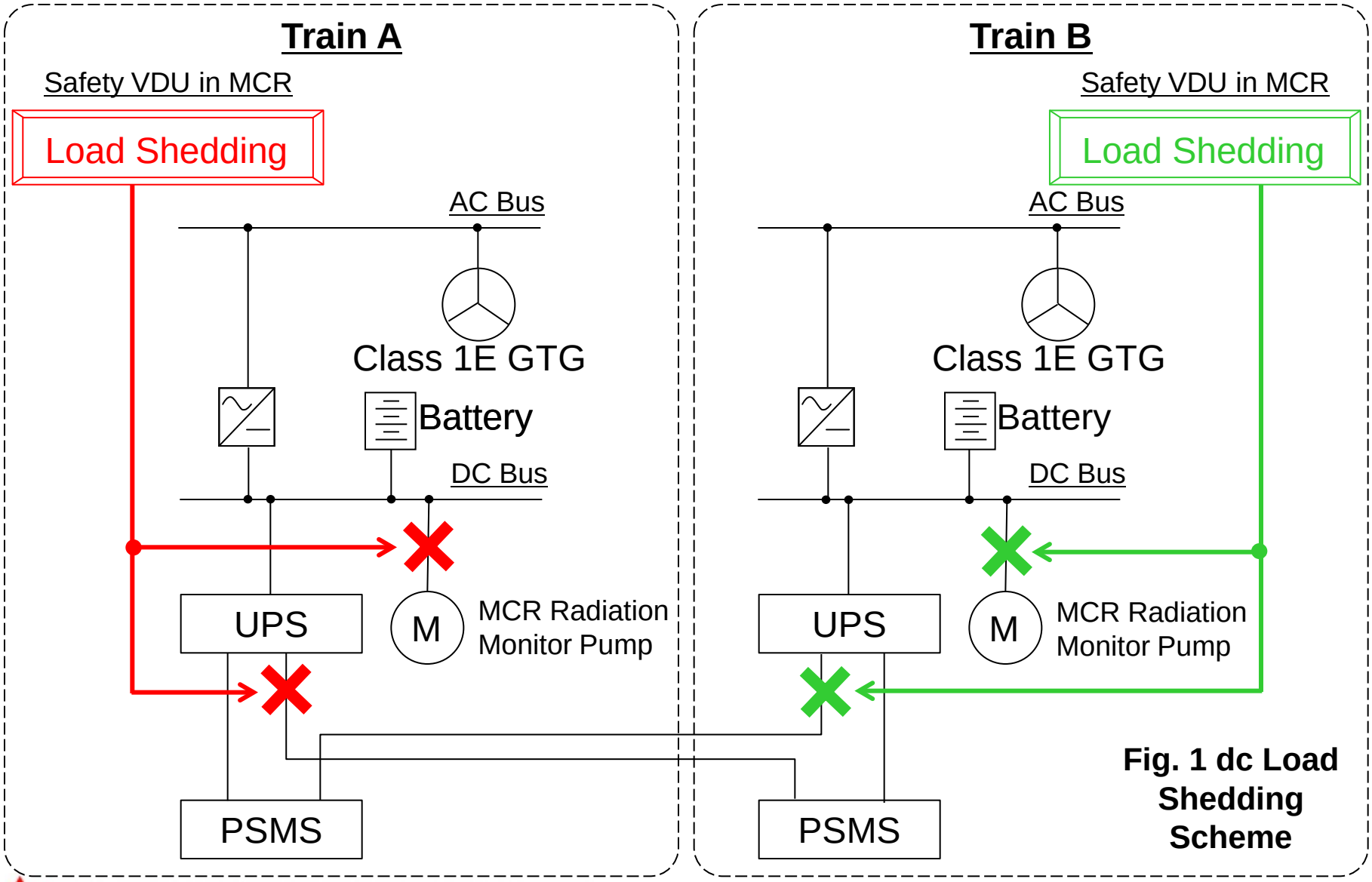


Fig. 1 dc Load Shedding Scheme

Alternate UHS

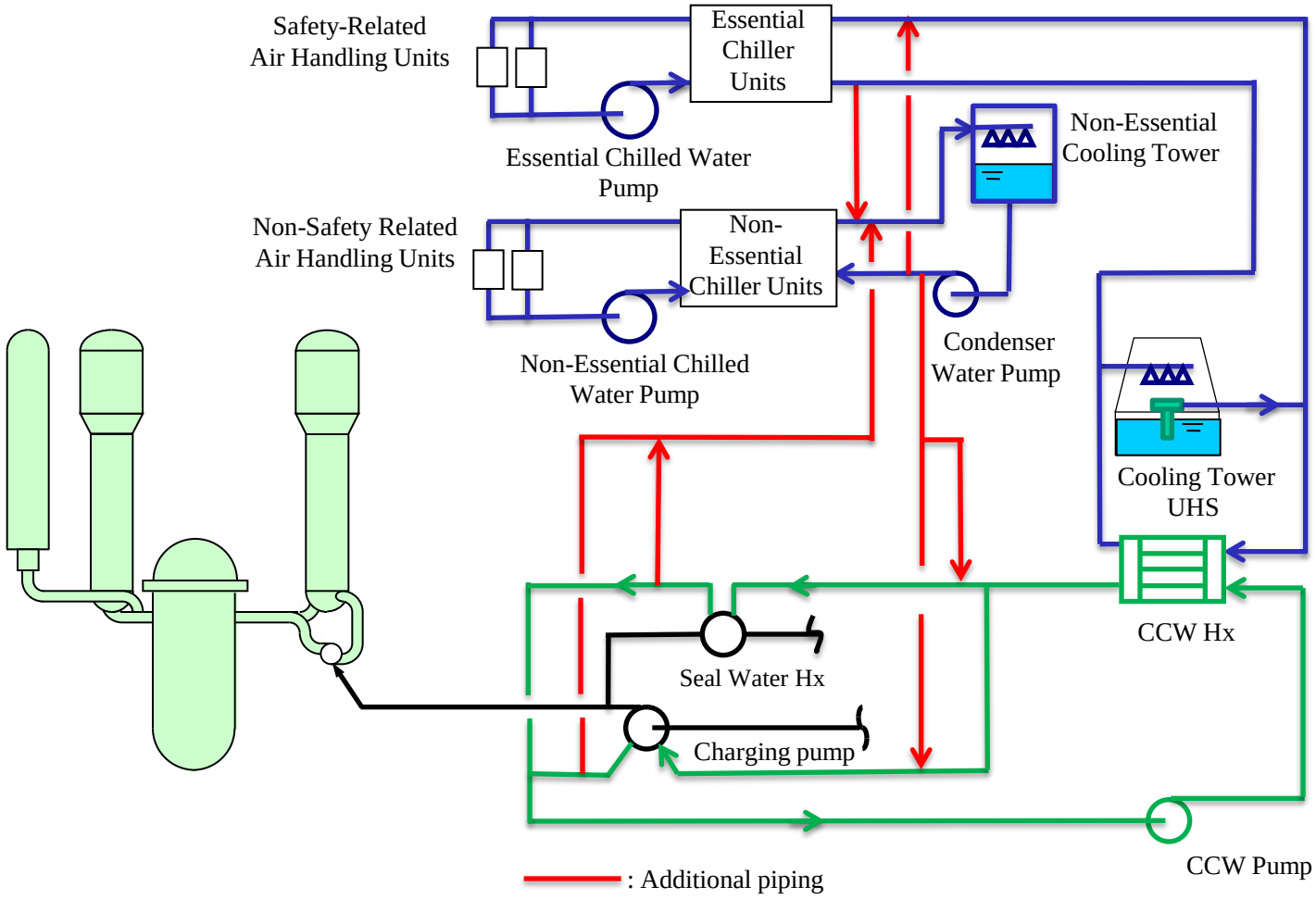


Fig. 2 Alternate UHS

Enhanced SFP Level Instrumentation

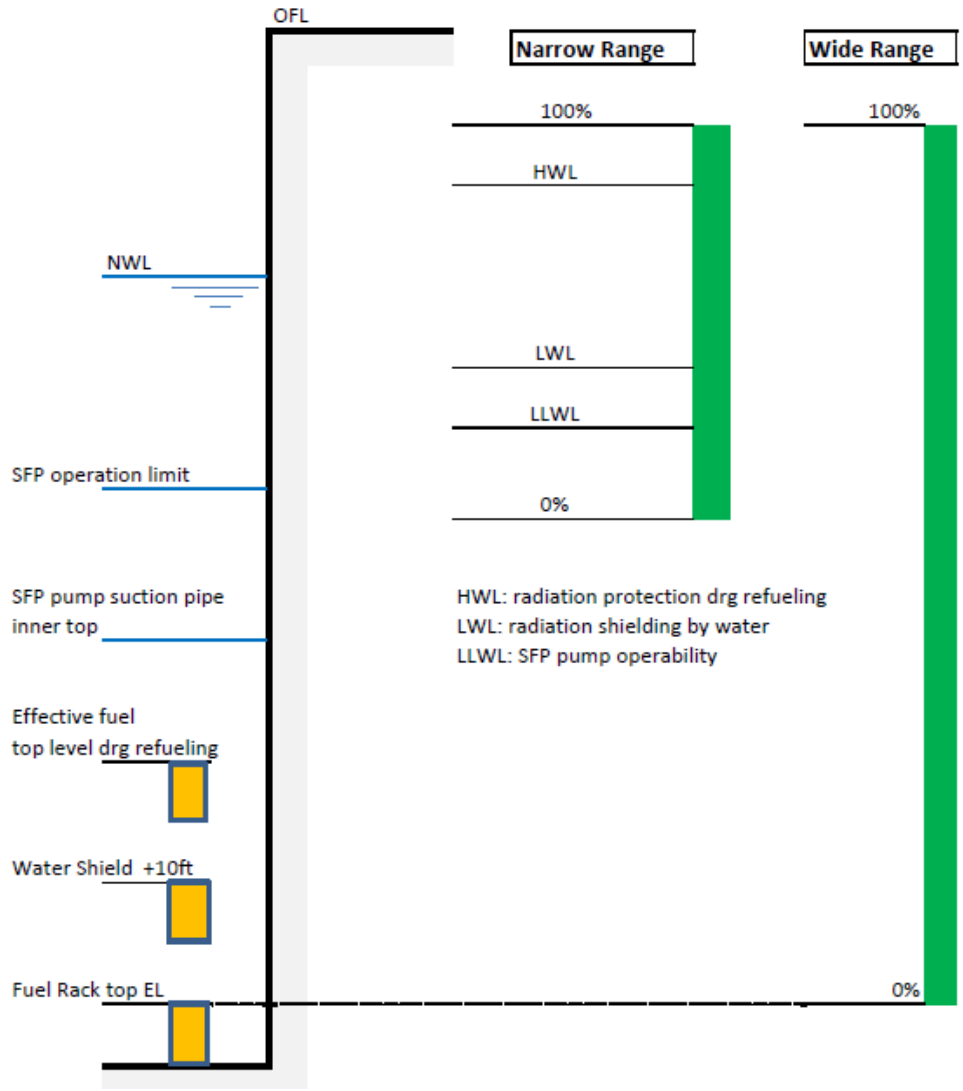


Fig. 3 Enhanced SFP Level Instrumentation

US-APWR FLEX Capability Summary (1/4)

Safety Function		Method	Baseline Capability	FLEX Equipment
Core Cooling	Core cooling	• EFWS-SG-MSSV/MSDV • Sustained Source of Water	• Use of installed equipment (EFWS-SG-MSSV/MSDV) for initial coping • Use of alternate water supply (DWST), if available • Connection at EFW pit for portable pump to supply water from UHS basin	• On-site self-powered portable pump to makeup EFW Pits , hoses, couplings • On-site self-powered portable pump to directly supply water to SG in a depressurized condition
	RCS Inventory/Boration	• Low Leak RCP Seals • Provide borated RCS makeup	• Low-leak RCP seals, cooled by seal water injection by a CHP • CVCS Makeup and Accumulators for boration • CVCS seal water injection • Suction piping from RWSP and Emergency letdown line to RWSP	• None

US-APWR FLEX Capability Summary (2/4)

Safety Function		Method	Baseline Capability	FLEX Equipment
Core Cooling (Cont)	Key Reactor Instrumentation	• SG Level • SG Pressure • RCS Pressure • RCS Temperature	• Instruments powered by class 1E dc bus	• None
Containment	Containment Pressure Control/Heat Removal	• Containment Structure • Containment Spray	• Large dry containment	• None
	Key Containment Instrumentation	• Containment Pressure	• Instruments powered by class 1E dc bus	• None
SF Cooling	SF Cooling	• SFP makeup	• Use of installed equipment (RWS pit-RWR Pump) • Additional makeup lines and SFP spray lines • FSS stand pipes, if available	• On-site self-powered portable pump to makeup SFP
	SFP instruments	• SFP Level instrumentation	• Two sets of wide range safety-grade continuous SFP level instruments • Two sets of narrow range safety-grade continuous SFP level instruments	• None

US-APWR FLEX Capability Summary (3/4)

Safety Function		Method	Baseline Capability	FLEX Equipment
Support Function	ac power	• Alternate ac power source • ac distribution system	• AAC and ac distribution system installed in PS/B* * Seismic cat. I and enhanced flood protection	• None
	dc power	• Alternate ac power source via battery charger • dc distribution system	• AAC and dc distribution system installed in PS/B*	• None
	Cooling water for components	• Alternate UHS	• Non-essential Chiller C/T installed on A/B roof (seismic cat. II and flood protection) • Connection to ESWS for Essential Chillers and CCWS for CHPs and Seal Water Heat Exchanger • Connection at Non-essential Chiller C/T for portable pump	• On-site self-powered portable pump to makeup Non-essential C/T, hoses, couplings

US-APWR FLEX Capability Summary (4/4)

Safety Function		Method	Baseline Capability	FLEX Equipment
Support Function (Cont)	HVAC	• HVAC system for MCR, Essential Chiller Unit Area, Charging Pump Area , Class 1E Electrical Room and T/D EFWP Room	• HVAC system for MCR, Essential Chiller Unit Area, Charging Pump Area , 1E Electrical Room and T/D EFWP room	• None
	Lighting	• Emergency lighting systems	• 1E emergency lighting powered by 1E 125V dc system • Emergency lighting with self-contained battery • N/E lighting system powered by AAC	• None
	Communication	• Communication systems	• Plant communication systems (PABX, SPTS): to be evaluated	• None
	Fuel oil	• Portable fuel oil supply	• Connection for fuel oil refill is equipped.	• External resources
	Makeup water	• Makeup water source	• DWST • UHS basins	• See the FLEX equipment for Core Cooling, SF cooling and Cooling water for components

Questions and Comments