Polish Electrical Requirements for Nuclear Power Plants

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ABWR Technology & Design

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About us - company profile

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HITACHI
Inspire the Next
Hitachi, Ltd.

imagination at work
General Electric Company

Hitachi equity share:
80.01%

GE equity share:
19.99%

Hitachi equity share:
40%

GE equity share:
60%

Hitachi-GE Nuclear Energy
(Established on July 1, 2007)

GE Hitachi Nuclear Energy
(Established on June 4, 2007)

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Synergy

Hitachi-GE Strength
- Full System Design
- Manufacturing
- Construction
- Integrated CAE
- Advanced Technology

Systems Design

GE-Hitachi Strength
- NSSS Design
- Global Execution-NPP, Services, Fuel
- Global Supply Chain
- Advanced Technology
- Licensing

- GE-Hitachi alliance based on nuclear business collaboration for 50 years
- Committed to develop and promote latest BWR technologies and services

ABWR - advanced and proven technology

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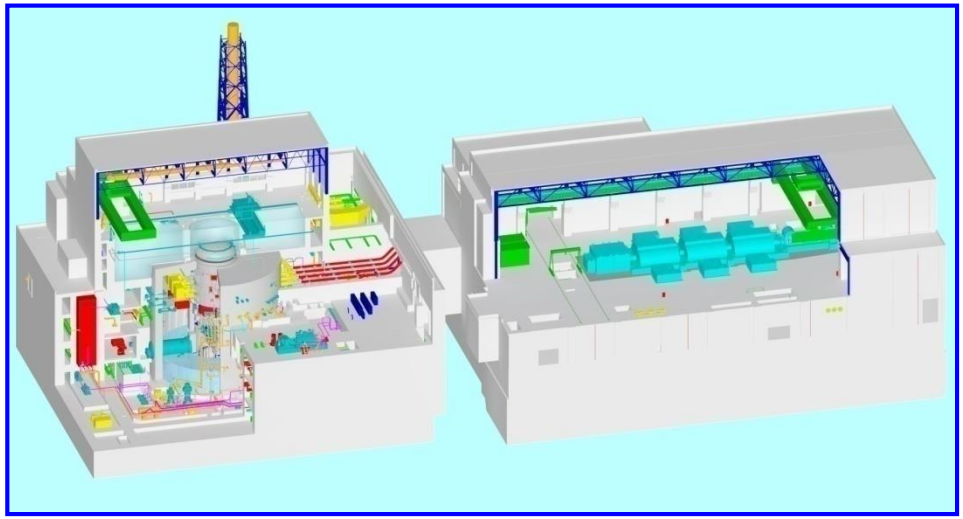
Most experienced Generation III+ reactor in the world … advanced, proven and operating

- Safe, reliable and cost competitive
- Simplified systems with high operability
- Short & credible construction
- Design certified by the US-NRC, 1997
- First license approved in 1991; 5 ABWRs in Japan



1350 MWe class

World's 1st & 2nd ABWRs: Kashiwazaki-Kariwa 6&7
(Operation start : 1996 & 1997)

ABWR evolution

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ABWR technology is always evolving

- Incorporating customer requirements, site conditions and
- Improvements based on plant operating experience and technological advancements


Kashiwazaki-Kariwa Unit 6 & 7


Shika Unit 2


Ohma Unit 1 *


Hamaoka Unit 5


Shimane Unit 3 *


Taiwan Lungmen Unit 1 & 2 *

· KK-6&7
First Standardized Design.

1990

1995

· Hamaoka-5
First 60Hz Turbine- Generator

2000

· Shika-2
High Seismic Requirement
High Performance Initial Core Design

2005

· Shimane-3
Rationalization of NSSS

2010

· Ohma-1
Full MOX ABWR

2015

· UK-ABWR
Fukushima Countermeasure

Avoid FOAK Risks

Proven Technology

*before commercial operation

Horizon project schedule

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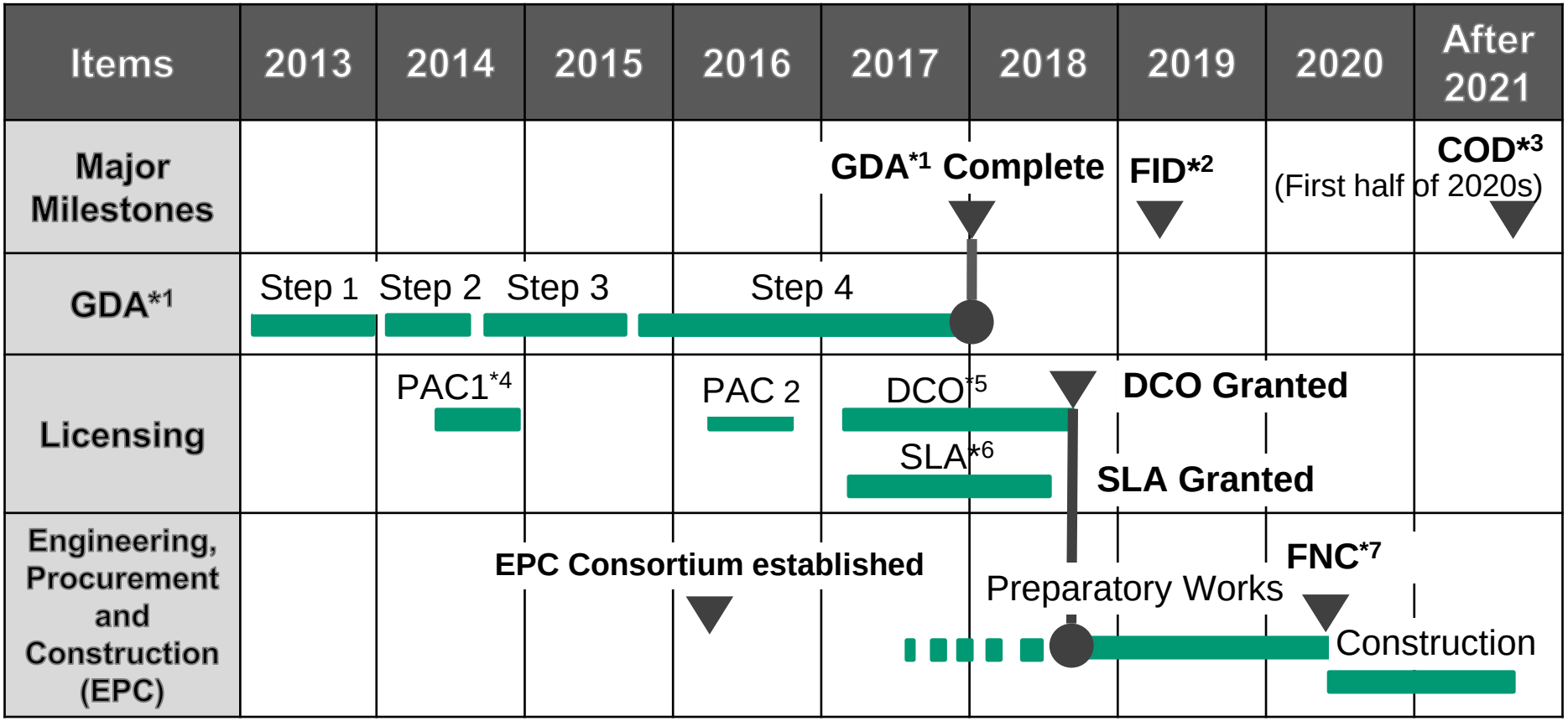

Near-term milestones

- Dec. 2017, GDA (safety assessment) ***complete*** … 5 year process
- Mid-2018, DCO granted … start significant site work
- Site licensing well underway ... supports mid-2020 construction start
- ***All on schedule and on budget***

*1:Generic Design Assessment
*2:Final Investment Decision
*3:Commercial Operation Date
*4:Pre Application Consultation
*5:Development Consent Order
*6:Site License Application
*7: First Nuclear Construction

Key plant / reactor characteristics

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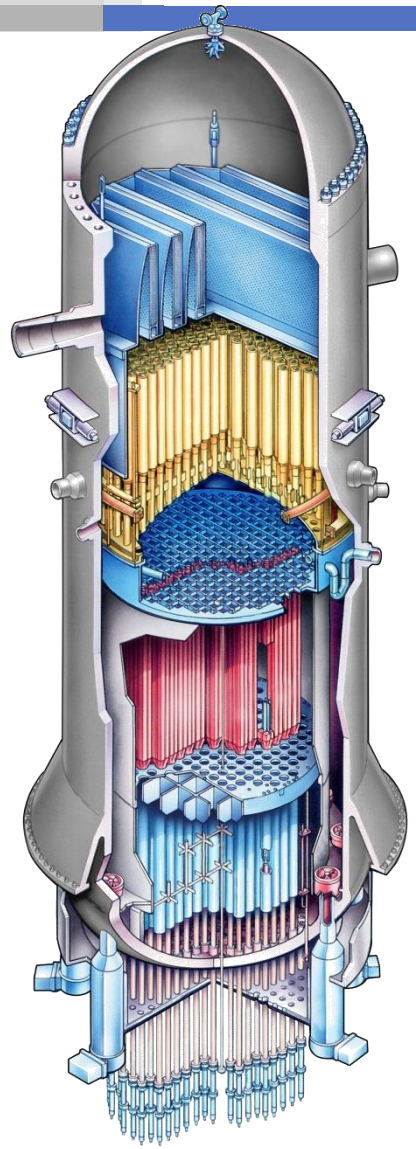
ABWR Parameters

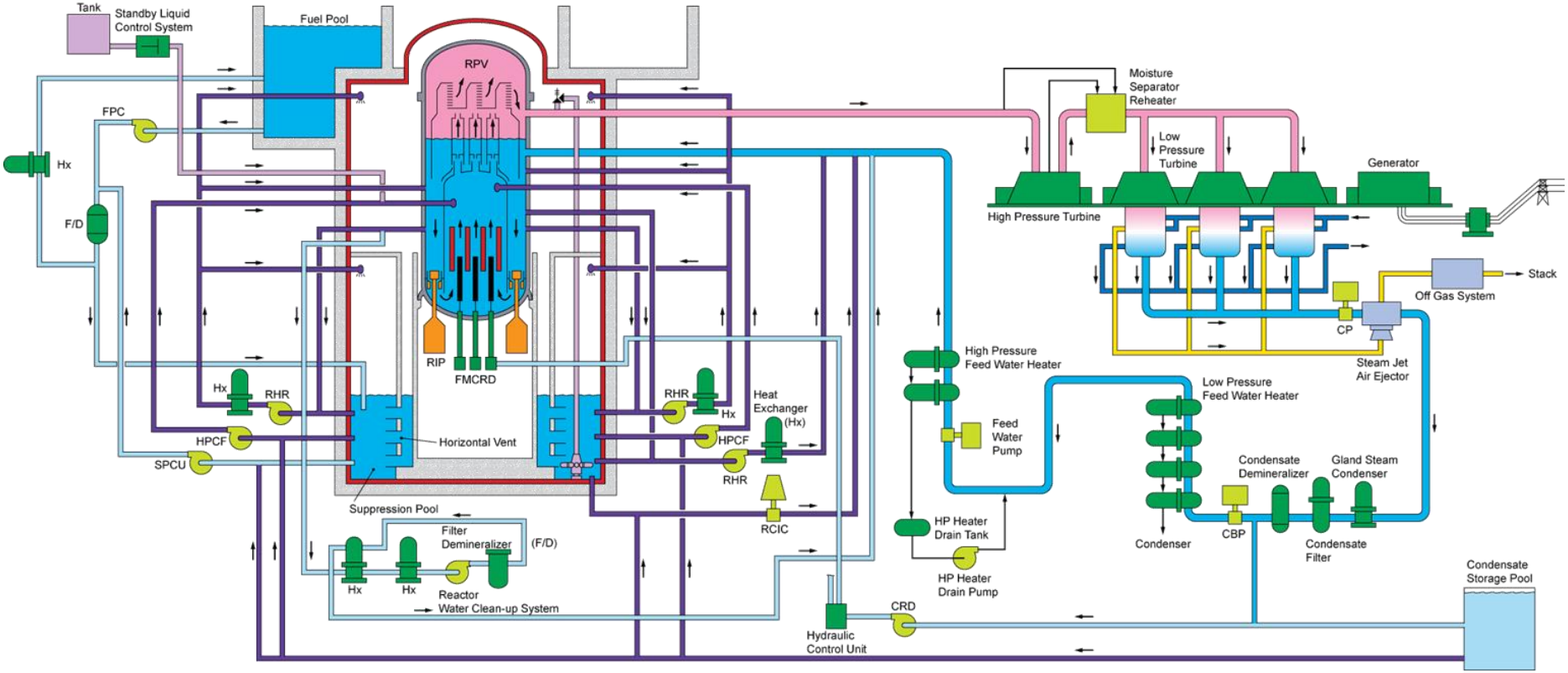
- Core Thermal Power Output ……. 3926 MWt
  - Uprate capability …….. 4300 MWt
- Plant Net Electrical Output[1]……. 1350 MWe
- Reactor Operating Pressure …….. 7.17 MPa
- Feed water Temperature[2] …… 216°C
- RPV
  - Diameter …… 7.1 meters
  - Height …… 21 meters
- Reactor Recirculation …… 872 fuel bundles
- Fuel length …….. 3.66 meters
- Average power density …….. 51 kW/liter
- Control blades …… 205 fine motion control rod drives



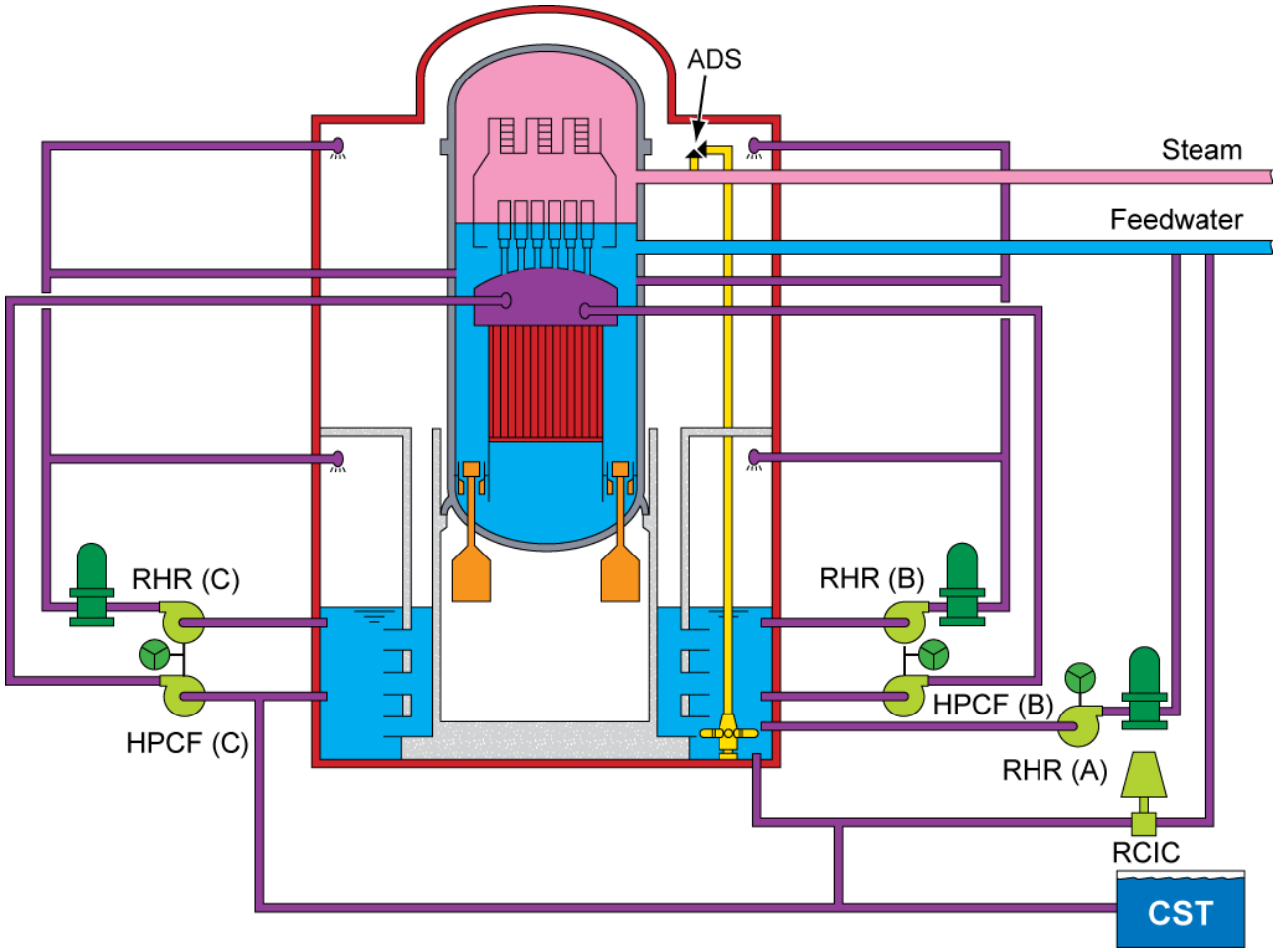
[1] Typical (site dependent)

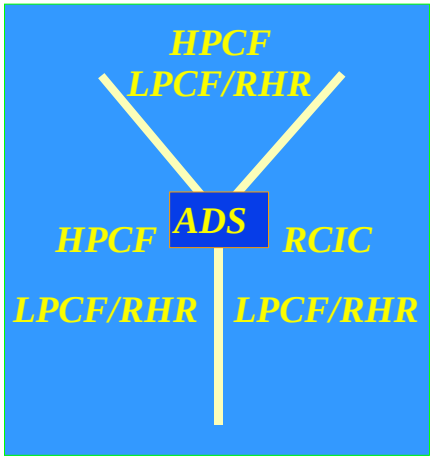
[2] Nominal Rated Operation

ABWR Overall Flowchart



ABWR Emergency Core Cooling Systems (ECCS) (safety classified)





Essential Support Systems (safety classified)

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Electrical

- Emergency Diesel Generators (EDGs)
- Switchgear
- Load Centers
- Motor Control Centers
- Uninterruptible Power Supplies
  - Batteries, Inverters, and Rectifiers

Cooling Water

- Reactor Service Water (RSW) (open loop)
- Reactor Cooling Water (RCW) (closed loop)

Heating, Ventilating and Air Conditioning (HVAC)

- Local Fan Coil Units
- General Area Conditioning

Pneumatic

- Stored in properly sized accumulators

High Level Objectives for Nuclear Power Plant

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- Maintain cooling of the nuclear fuel at ALL times
  - In the reactor during power operation
  - In the reactor when shutdown
  - In the reactor during an accident
  - In the spent fuel pool
- Remove decay heat
  - From the reactor
  - From the primary containment
  - From the spent fuel pool
- Decay heat
  - ~80 MWt at 15 minutes after shutdown
  - ~32 MWt at 8 hours after shutdown
  - ~24 MWt at 24 hours after shutdown
- Generate electricity reliably and efficiently

Safety-Related versus Non-Safety Related

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Need to avoid negative interactions between equipment of different safety classes

A preferred way to ensure this is to:

- Physically separate the equipment/systems
- Provide electrical separation of equipment/systems
- Protection against Common Cause Failure (CCF)
  - Require diversity between safety and non-safety equipment/systems
  - Level of Diversity required can vary but should be as large as reasonably practical

Likely will be a need for equipment that does not utilize embedded digital devices in some instances

Basic Design Philosophy

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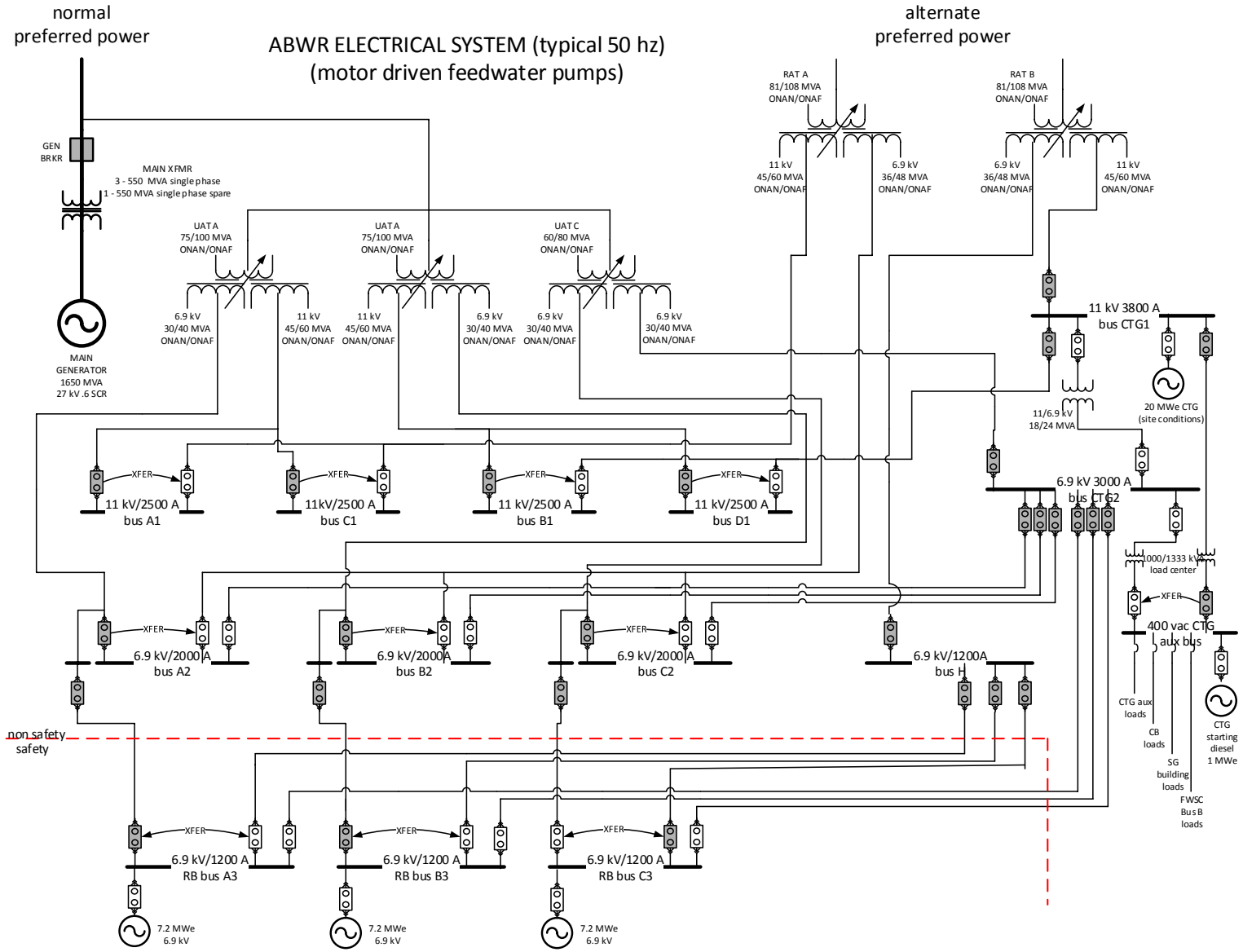
Single Failure Proof plus Division Out of Service

- N+2
- 3 divisions mechanical and electrical
  - Physically Separated
  - Use of distance without physical barrier not typically acceptef

Four Divisions of Digital Control and Instrumentation

- Reactor Protection System (RPS)
  - Fail Safe
- Engineered Safety Features
  - Fail as Is

ABWR MV Electrical System (conceptual)



ABWR Key Design Features – Onsite Power

Emergency Diesel Generators (EDGs)

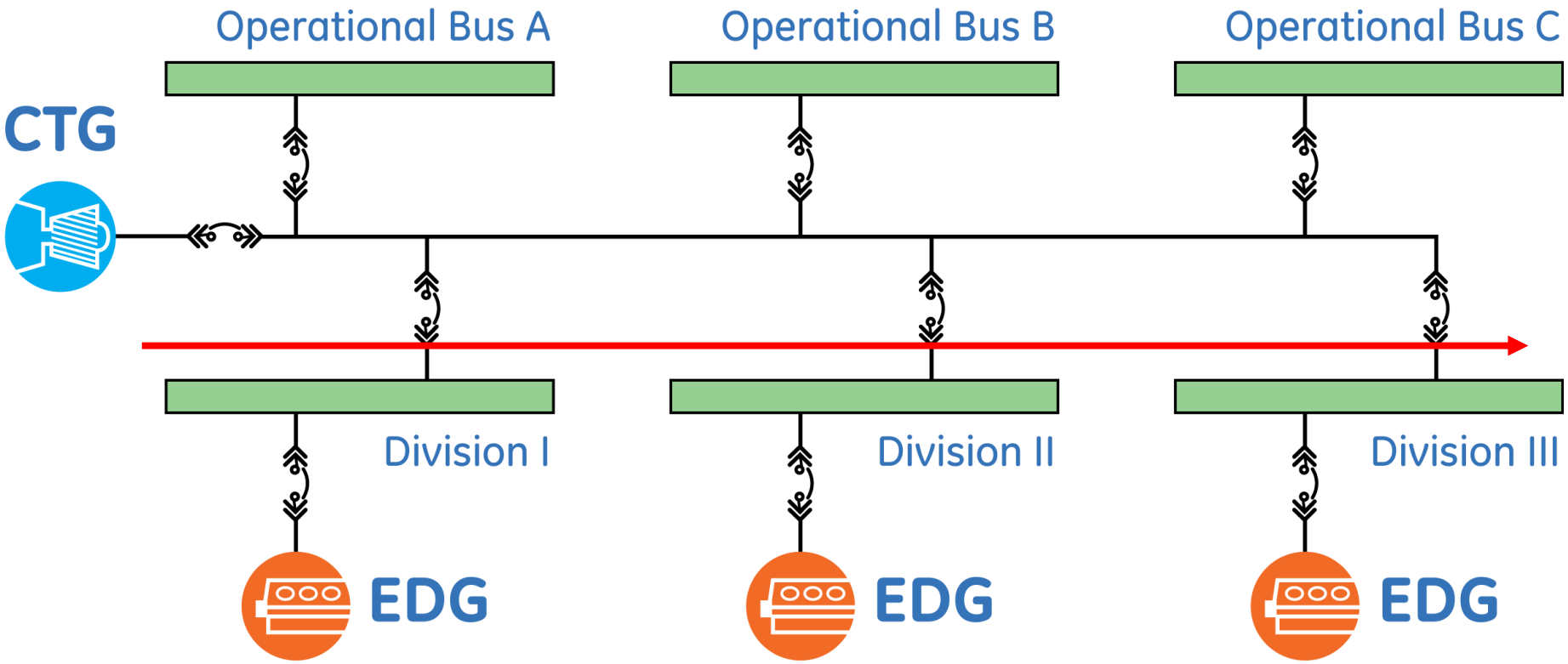
- 3 located in separate buildings next to Reactor Building
  - Grade elevation
  - Each has an 8-hour day tank in the EDG room
- Each has a 7-day fuel tank that is buried in a concrete vault outside the RB
- Need Reactor Service and Cooling Water (RSW) and (RCW)
- Safety-related switchgear is located in the RB

Alternate AC Power Source (AAC)

- Combustion Turbine Generator (CTG)
  - Air-cooled – Service Water not needed
- Other AAC schemes are possible

Safety-related batteries are located in the CB just below the MCR

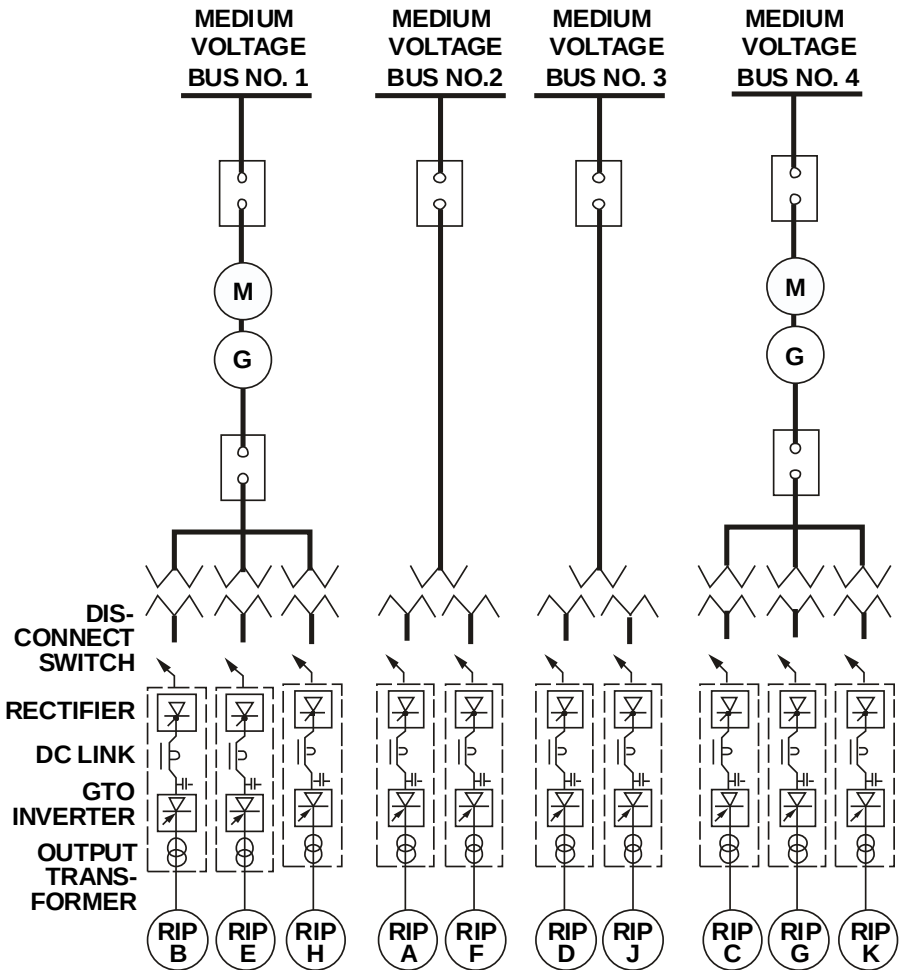
ABWR Key Design Features – Onsite AC Power



RIP Power Supply (existing configuration)

- Reactor Internal Pumps (RIP) motor driven by solid-state variable frequency power supply: Adjustable Speed Drive (ASD)
- Each RIP driven by dedicated ASD:
  - 6 RIP ASDs receive power from constant speed Motor-Generator (M-G) sets with Flywheels
  - 4 RIP ASDs receive power from medium voltage buses

Other arrangements are being evaluated



ABWR LV Electrical System (conceptual)

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Slide Withheld

Types of Electrical Equipment

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Generators
- Main
- Emergency Diesel
- Combustion Turbine
- Motor-Generator

Transformers

Switchgear

Load Centers

Motor Control Centers

Adjustable Speed Drives

Motors

Cable
- Single Conductor
- Multi Conductor
- Mineral Insulated
- Fiber Optic

Uninterruptible Power Supplies
- Batteries, Inverters, and Rectifiers

Instrumentation

Equipment Qualification (EQ)

Demonstration that the equipment will reliably perform as required when:

- Equipment is at its qualified age, **AND**
- Is exposed to the environment created following an accident

Equipment must operate for:

- Required mission time, OR
- At least 30 days following the accident

Demonstration can be a combination of test and analysis

- Similar equipment

Note the basic design life is 60 years

- Replacement is allowed but not preferred

EQ can present a **long** and difficult task for vendor not familiar with the process

Testing facilities may be limiting

Synergies between aging phenomena need to be understood

Equipment Qualification

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Safety-Classified

- Harsh Environment (inside primary containment)
- Mild Environment (Reactor, Control and Heat Exchanger Buildings)

Parameters

- Pre-accident normal operation
- Post accident
  - Temperature
  - Radiation
  - Humidity
  - Moisture (spray or submergence)
  - Seismic

Requirements profile provided by plant designer

Lower Safety Classes

- Less Significant and not applicable in many cases

Other Requirements

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Nuclear Approved Quality Assurance Program

- Safety Class Equipment

IEC

- 61508 (general)
- 60780
- 60880
- 62138
- 62340 CCF in embedded digital devices

European Union Directives

Country and Local

Embedded Digital Devices

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Evolving Concern with Common Cause Failure (CCF)

- Unintentional Errors
- Software
- Hardware
- Malicious Intent
- Internal
- External

Significant challenge to vendors

- Many vendors may decide the level of effort is too much
- Trade off of digital benefits versus old style analog logic

Acronyms

ADS	Automatic Depressurization System
CB	Control Building
CCF	Common Cause Failure
CDF	Core Damage Frequency
CTG	Combustion Turbine Generator
DBA	Design Basis Accident
EDG	Emergency Diesel Generator
ECCS	Emergency Core Cooling System
FPCU	Fuel Pool Cooling and Cleanup
HPCF	High Pressure Core Flooder
LPFL	Low Pressure Flooder
MCR	Main Control Room
RB	Reactor Building
RHR	Residual Heat Removal
RPV	Reactor Pressure Vessel
RCIC	Reactor Core Isolation Cooling
RCW	Reactor Building Cooling Water
RSW	Reactor Building Service Water
RWCU	Reactor Water Cleanup System
SBO	Station Blackout
SFP	Spent Fuel Pool
SP	Suppression Pool
SRV	Safety/Relief Valve
TSW	Turbine Building Service Water
TCW	Turbine Building Cooling Water

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Thank You
Dziękuję

Hitachi-GE Nuclear Energy, Ltd. JAPAN
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http://www.hitachi-hgne.co.jp/en/index.html