ATMEA

Atoms for the Future – SFEN JG

Operability of Generation III NPPs

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Introduction

- **What is Generation III NPP?**
  - **Large improvement in safety, economy and reduced waste generation**
- **From operation point of view, how a new NPP is designed to improve these?**
  - **Improvement of safety and/or operability may degrade economy. How is it compensated?**
  - **What are the targets of improving operability or operation performances?**

  - **Introduce concepts and designs taking our reactor as an example**

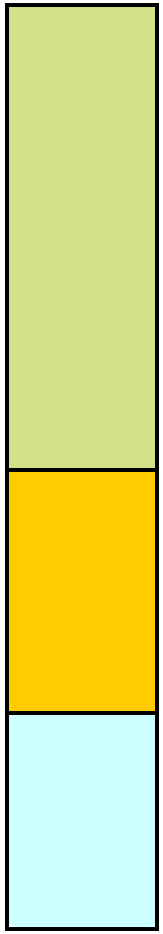
Introduction
ATMEA and ATMEA1

- **ATMEA is a joint venture between AREVA and Mitsubishi Heavy Industries, to design, Marketing & Sales, Construction & Commissioning of ATMEA1 nuclear island**

- **ATMEA1 is 1100MWe class Generation III+ reactor**

Reactor Type	3-Loop PWR	Safety System	3+1 Train reliable active system with passive features
Electrical output	1100 – 1150 MWe (Net)	Severe Accident Management	Core catcher Hydrogen re-combiners
Core	157 Fuel Assemblies	Resists airplane crash	Pre-stressed Concrete Containment Vessel
Steam Pressure	More than 7 MPa	I&C	Full Digital

Introduction
Key Cost Features of NPP

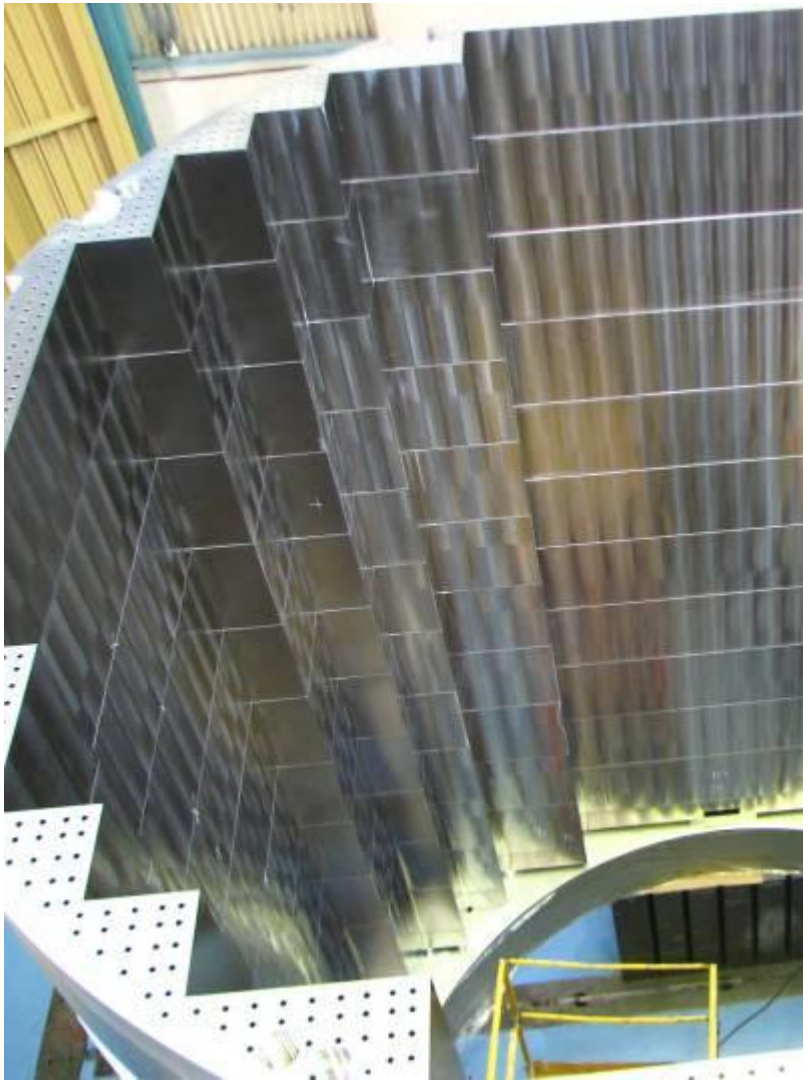


- **Generation cost ($/kWh) = Key parameter of economy**
  - **Capital cost**
    - **= Construction cost annual amortization / annual generation of electricity (kWh)**
      - Civil work, buildings, equipment
      - Design cost
      - Decommissioning cost
      - Interest
  - **Fuel cycle cost**
    - **= Fuel related cost per cycle / generation of electricity (kWh)**
      - Uranium, conversion, enrichment, fabrication
      - Spent fuel storage, transport, recycling
  - **Operation and maintenance cost**
    - **= Operation and maintenance cost per cycle / generation of electricity (kWh)**
      - Cost of operators
      - Cost of maintenance and outage

Design Concept of ATMEA1 from Operation Point of View

- **Maximize benefits through its life time**
  - Design optimized to minimize LCOE (levelized cost of electricity)
  - Naturally, more focus on operation and maintenance
- **Typically characterized by:**
  - Longer plant life (60 years ← 30 – 40 years for Gen.II)
  - Higher thermal efficiency (~36% ← ~33% for Gen.II, i.e., +10% more generation)
  - Higher availability factor
    - Shorter outage
    - Flexibility of operation cycle length (12 – 24 months)

Design Measures 60 Years Life



- **Main design issues to assure 60 years life**
  - **Neutron irradiation embrittlement for RPV**
  - **Fatigue taking transient cycles for 60 years**
  - **Erosion/corrosion, SCC**
- **RPV design is one of the key (not easy to replace)**
  - **Heavy neutron reflector + wider down-comer**
    - **Neutron fluence <2E19n/cm2 for 60 years, that is 5-10 times less than typical Gen.II PWRs**
    - **Remove risk of SCC by removing all bolts in high fluence region**
  - **Top mounted instrumentation removing all penetrations from the bottom**
  - **Material selection against SCC (e.g., TT690 for nozzles)**
- **Such design also reduces inspection workload during outages**

Design Measures Thermal Efficiency

- **High thermal efficiency is the key:**
  - To reduce generation cost by saving fuel consumption and maintenance cost
  - With less impact on capital cost
  - Also to reduce waste generation

Electrical output	1,100 – 1,150 MWe
Thermal output	3,150 MWth
Tavg / Thot	309 / 326 deg-C
Cooling flow rate	24,800 m3/h/loop
Thermal margin	>15 %
Steam Generators	Around 24,000 m2 with axial economizer
Steam pressure	7.3 (MPa)
Net efficiency	35 – 37 %

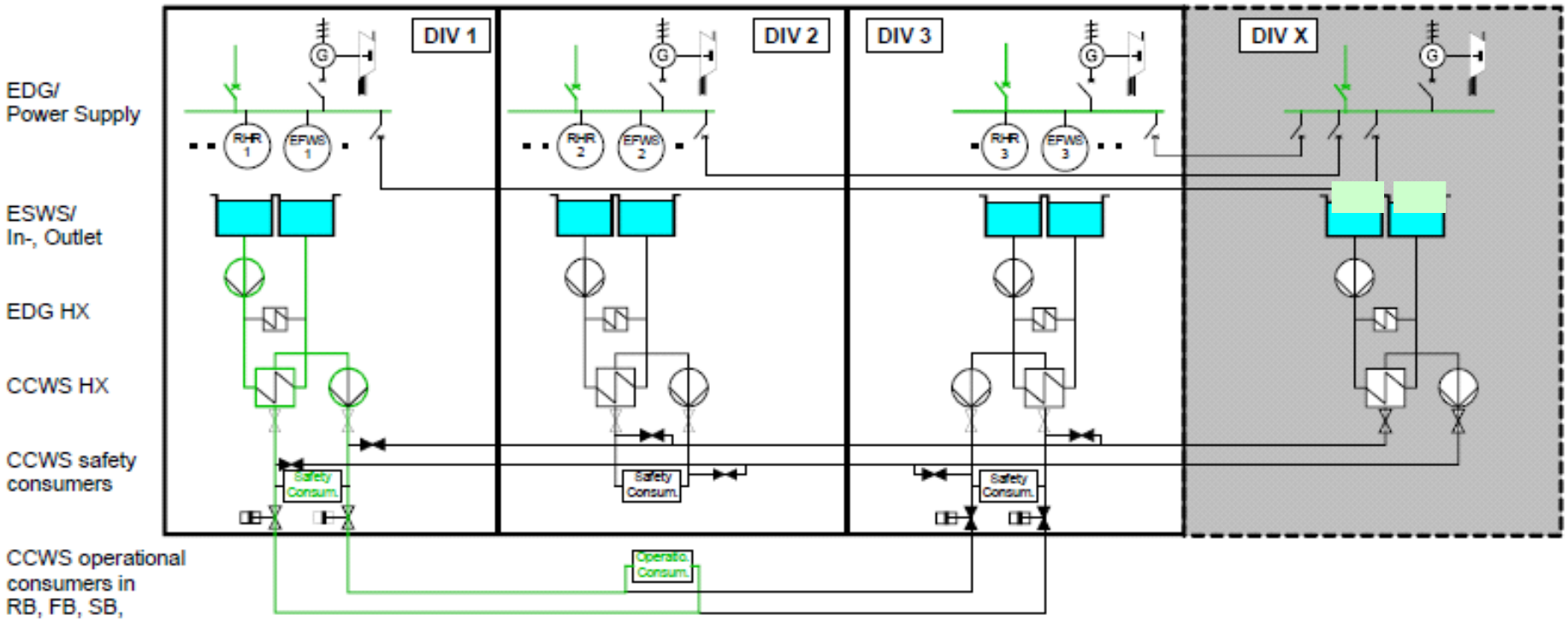
- **Generate electricity with 10% less thermal output**
  - High average primary temperature
  - Efficient SGs with optimized heat transfer area and axial economiser

Design Measures Availability Factor

- **High availability factor is the key to maximize output and to reduce capital cost**
- **Designs to achieve high availability factor**
  - **Outage duration: <16 days for normal refuelling outage**
    - **<u>On-power maintenance</u> by redundancy of support system**
      - **Maintenance work is the critical path of an outage**
        → On-power maintenance reduces maintenance work during an outage
    - **<u>Accessible Reactor Building</u> Design during operation (2 room concept)**
      - **Accessible design during operation allows preparation work of maintenance in parallel with operation**
    - **<u>Adequate space for maintenance and inspection</u>**
      - **This allows maintenance and inspection work be efficient**
  - **Flexibility in operation cycle length without increasing fuel cycle cost: 12 – 24 months cycle**
- **These characteristics also contribute to relax peak and level maintenance workload**

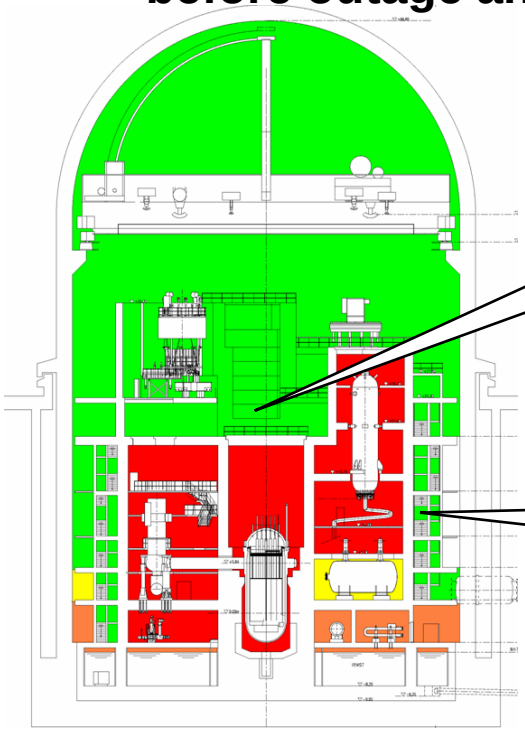
Design Measures - Availability Factor On-Power Maintenance

- **Critical systems for maintenance during outages are cooling chain and emergency power sources (diesel generators)**
- **<u>3 trains plus one additional diversified train</u> for cooling chain and emergency power sources**
  - **Preventive or corrective maintenance of any other train during power operation (OPM: On Power Maintenance) by connecting Division-X**
  - **Division X also provides diversification in cooling equipment, and heat sink (Against common cause failure)**

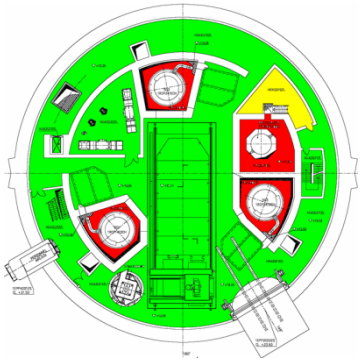


Design Measures - Availability Factor
Two Room Concept

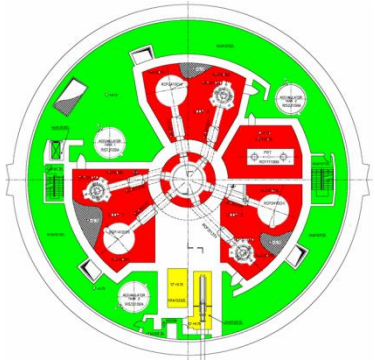
- The **"Two room concept"** allows for accessibility into the Reactor Building during power operation for maintenance preparation works before outage and clean up after outage



Operating floor is accessible during power operation



Annular space is accessible during power operation



Maintenance preparation before outage

- Test of the polar crane
- Test and maintenance of the refueling machine and fuel transfer device
- Multi Stud Tensioning Machine
- Other outage works preparation

Normal Refueling Outage: <16 days

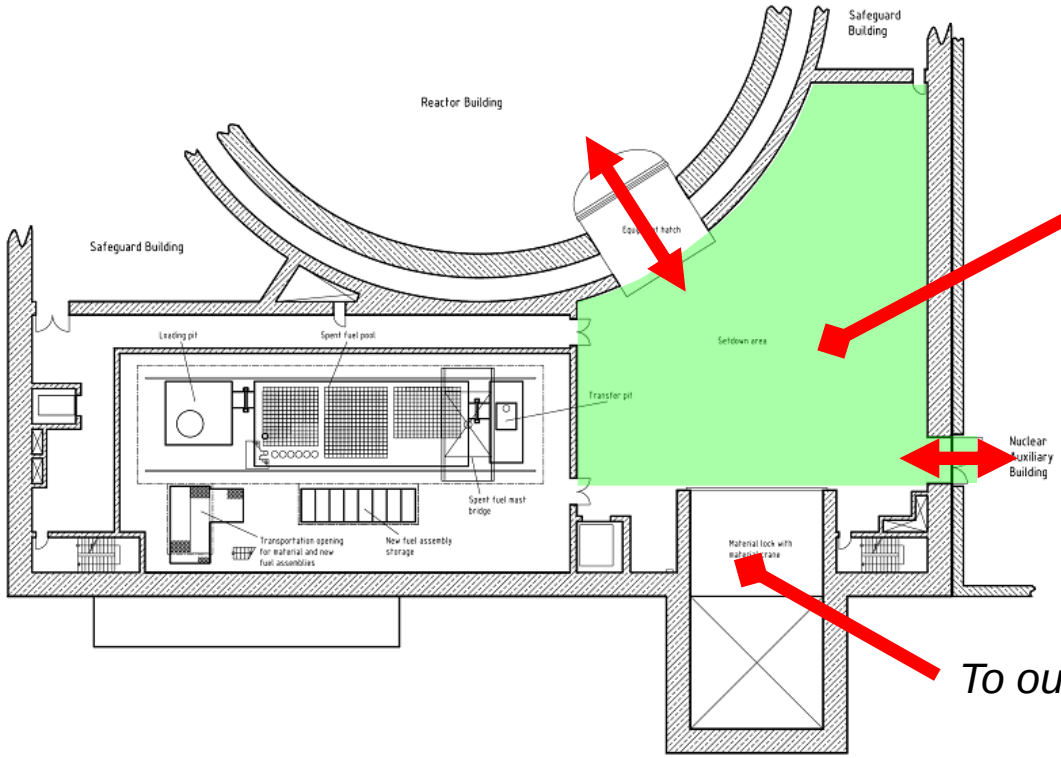
- Plant shutdown/start up
- Vessel head opening/closing
- Fuel unloading/loading
- Maintenance/Inspections

Clean up after outage

- Clean up

Design Measures - Availability Factor
Layout of Maintenance Space

- **To make maintenance easier, a large setdown area is provided in front of the equipment hatch (operating floor level)**
  - **It is connected to the outside by a material lock with material crane for transportation of service equipments, material, spare parts etc**
  - **it is also connected via a large door to the maintenance and setdown area of the Nuclear Auxiliary Building**



This sketch shows the Large set-down area

- *In front of equipment hatch*
- *Connected to Nuclear Auxiliary Building*

To NAB

To outside

Design Measures - Availability Factor Operation Cycle Length

- **Flexibility of operation cycle length is important for each operator to optimize operation/maintenance cost and availability factor**
- **Long operation cycle like 24 months have not been popular in PWR mainly due to:**
  - **Increase of fuel cost (>1/2core needed to be replaced by new fuel)**
  - **Limitation in fuel burnup and enrichment**
  - **Necessary maintenance intervals**
- **Design measures**
  - **Medium power density of the core together with the latest fuel technology**
  - **Stretch out operation at the end of cycle**
  - **On-power maintenance**

Examples of fuel management and economy

Fuel	UO2			1/3 MOX
Operation cycle	18m	12m	24m(*)	18m
Av. Discharge BU (GWd/t)	52	56	52	52

**: 2 batches fuel loading including stretch out operation (40 EFPD)*

Another Important Operational Aspect not only Generation Cost

- **NPP, lives together with people**
  = workers, people living around NPP
  - **First, safety**
    - **Much less impact on people even under extreme condition (e.g., long term containment integrity, no evacuation, etc.)**
  - **Working environment and radio protection of workers**
    - **HFE, layout, shielding, HVAC, material selection, purification system, water chemistry, …**
  - **Levelling of maintenance workload**
    - **On-power maintenance**
    - **Two room concept**
    - **Reduction of necessary inspection by design (e.g., less welding)**
  - **Protection of environment**
    - **Less waste generation**
    - **Recycling, less release**
- **These are not negation of economy but contributors**

- **An open question (especially after Fukushima):**
  "Are we really living together?"

As Conclusions

- **“Design improving operability” is one important way to improve economy, and in many cases, contributes to safety**
- **Generation III design is not a completely new design, but it shall be designed utilizing all our experience feedbacks**
- **Two important points of view:**
  - **A NPP operates long like 60 years**
  - **A NPP lives together with people**