NPP-Nuclear Island Design
From conceptual design to Project execution

Atoms for the Future
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NPP-Nuclear Island Design
From conceptual design to Project execution

- Introduction
- Conceptual phase
- Basic Design
- Project execution
- Conclusion
Introduction

- **Stakeholders:** Designer/Vendor, Utilities/Investor, Safety Authority, Government
- **Time measured in decade till project execution**
- **Huge financial and intellectual investment**
- **Sequences are well known but definition of each phases are arbitrary and boundaries between them could be fuzzy.**
  - Conceptual Design (relatively short)
  - Basic Design (several years)
  - Detailed – Manufacturing design (several years)

- **Focus on industrial models (not reactor at R&D phase)**
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Conceptual phase

What to be considered keeping in mind our stakeholders:

- Technical performance
- Economic and market goals (competition)
- Safety features, compliance with regulation, environmental aspects

Wide range of approaches between start from scratch or evolutionary

- level of investment and risks
Conceptual phase
Technical performance

- Type of reactor (PWR, BWR…)
- Power level, core size
- Number of loops (main equipment sizing)
- Flexibility in operation
- Type of Fuel, MOX capability
- Human factor
- Availability, maintenance in service, dose reduction
- Plant life time
- Capable of, in terms of climatic, seismic, environmental conditions (river, sea, water and air temperatures…)

RESTRICTED AREVA
Conceptual phase
Economic and market goals – competition

- Price for investment (total and €/KWi), for production (€/KWh)
  - Lead time
  - Construction time (modularity)
- Power level (Grid acceptability) and need for flexibility
- Proven technology
- Utilities requirements: EUR, EPRI-URD
Conceptual phase
Safety features, regulations, environmental aspects

- Compliant with GEN 3+ requirements + REX (i.e. post-Fukushima)
  - Core damaged frequency, Large release frequency
- AIEA, US regulations and codes and standards (US, Europe, Japan…)
- Licensibility for which country in front of which safety requirements
- Safety concepts:
  - Air Plane Crash
  - Passive and Active safety functions
  - Redundancy, Diversity, Number of trains
  - Severe accident strategy
  - Beyond design basis events
  - I&C concept (digital, analog, back-up)

- Waste quantities, Dismantling
### Key Benefits

<table>
<thead>
<tr>
<th>Business Performance</th>
<th>Outstanding Safety</th>
<th>Environmental Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>▶ Maximized availability design target &gt;92%</td>
<td>▶ Large commercial airplane crash resistance</td>
<td>▶ Lower volume of final waste</td>
</tr>
<tr>
<td>▶ Short outages</td>
<td>▶ Advanced features for core melt and releases management</td>
<td>▶ Reduced collective dose</td>
</tr>
<tr>
<td>▶ High thermal efficiency</td>
<td>▶ Optimized level of redundancy, diversity of systems and incremental mitigation of abnormal events</td>
<td></td>
</tr>
<tr>
<td>▶ Minimized global power generation costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>▶ Low O&amp;M costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>▶ Fuel cycle flexibility</td>
<td></td>
<td></td>
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<tr>
<td>▶ MOX fuel</td>
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### Energy Supply Certainty

- Gen III+ based on evolutionary designs
- Integrated supply chain strategy for critical components
- Proven Digital Safety I&C technology
EPR- The Best from French and German Technology

German KONVOI
(~1300 MWe)
- Neckar 2
- Emsland
- Isar 2

French N4
(~1450 MWe)
- Chooz 1-2
- Civaux 1-2

The EPR™ design is built on experience of over 100 plants, 87 of which are PWRs.
ATMEA1™, a Gen III+ Plant
Based on proven AREVA and MHI Technology

Improved economics, Enhanced safety, Minimized waste

High adaptability to Market
- 1,000 MWe range adapted to various grid capabilities
- Could cope with multiple country regulation
- High seismic areas, 50Hz/60Hz, …

Customer’s satisfaction for economy, reliability, and operability
- Superior efficiency and generation cost
- Competitive construction duration
- Flexible operation and maintenance capability

Relief of people around site area
- No evacuation required, less impact for environment
- Clear logic for Severe Accident, Air Plane Crash
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Basic Design
Before starting

- Freeze conceptual design (First step of configuration)
- Make sure high level requirements are exhaustive, clearly expressed and consistent.
- Identify possible customers support (possible external reviews, financing)
- Decide what will be the licensing strategy to get some approval in principle by a safety authority of the safety concepts used for the model

- And finally, set the goal for Basic Design output (and obviously budget and schedule)
  - Deepness of 3D model, I&C architecture, specifications, Bill of Quantities, construction principles, ready for quotation and offer.
Basic Design

- Select the regulations and codes on which the design works will be based
- Decide the methods and tools to be used (IMS, PLM…)
- Goal for basic design
  - Define the technical options which will enable to reach the performance, safety concepts and economics decided in the conceptual phase
  - Design, Integrate, verify and validate these technical solutions, (feasible, consistent, and meeting the conceptual phase requirements)
  - As far as possible, validation in principle of the safety concepts by the safety authorities
  - Plot plan, 3D model with Catalogues
  - Perform the necessary FOAK tests on new features
EPR Basic Design
Technical choices for severe accidents mitigation

Containment designed to withstand hydrogen deflagration

Containment Heat Removal System

Prevention of high pressure core melt by depressurisation means

In Containment Refueling Water Storage Tank (IRWST)

Spreading Area
Protection of the Basemat
EPR Basic Design
Protection Against Internal Hazards

Safeguard Building
Division 1

Safeguard Building
Division 2

Safeguard Building
Division 3

Safeguard Building
Division 4

Fuel Building

Nuclear Auxiliary Building
• Four Train Safety Injection Systems

• In-Containment Borated Water Storage Pool

• No Necessity for Containment Spray for Design Basis Accidents

• Combined Residual Heat Removal System and Low-head Safety Injection System

• Extra Borating System (two trains not shown on this figure)
• Two 25% Safety valves and one 50% atmospheric relief valve per Steam Generator
• Four separate Emergency Feedwater trains

• Interconnecting headers at EFWS pump suction and discharge normally closed
• Additional diverse electric power supply for two of four trains, using two small Diesel Generator Sets
## ATMEAl™ Basic Design
### Core Design Features

**Basic concept: Adopt proven / state-of-the-art technologies**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active core height</td>
<td>4200 mm</td>
<td>Same as EPR and USAPWR</td>
</tr>
<tr>
<td>Fuel assembly geometry</td>
<td>17x17</td>
<td>Same as those used in operating PWRs</td>
</tr>
<tr>
<td>Number of fuel assemblies</td>
<td>157</td>
<td>Same as 3 loop PWRs designed by AREVA or MHI</td>
</tr>
<tr>
<td>Fuel enrichment</td>
<td>&lt; 5.0 wt%</td>
<td>Same as operating PWRs</td>
</tr>
<tr>
<td>Max. fuel assembly burn-up</td>
<td>62GWD/t</td>
<td>Maximum value available without development</td>
</tr>
<tr>
<td>Control rod absorber material</td>
<td>AIC/B4C</td>
<td>Used in operating PWRs</td>
</tr>
<tr>
<td>Core monitoring/protection</td>
<td>Rh and Co SPND(*)</td>
<td>Used in operating PWRs (Rh) and EPR (Co)</td>
</tr>
<tr>
<td>Operation method</td>
<td>T-mode</td>
<td>Adopted in EPR</td>
</tr>
<tr>
<td>Chemical shim</td>
<td>Enriched Boron</td>
<td>Adopted in EPR</td>
</tr>
</tbody>
</table>

(*) SPND: Self-Powered Neutron Detector
ATMEA1™ Basic Design
Reactor Building 3D views
ATMEÅ1™ Basic Design
I&C Architecture

SICS
Mainly to Safety related
Level 1 I&C Systems

RPS
To PACS

SAS
To PACS

PACS
From other I&C systems

Rods

Safety systems

SA
To PACS

PAS
To PACS

DAS
To PACS

RCML

Level 2

Level 1

Level 0

Non safety systems

Rods

instrumentation

actuators

I&C Systems

To PACS

To all Level 1 non safety I&C Systems

Mainly to Safety related Level 1 I&C Systems
ATMEAn™ Basic Design
Objective: high availability

- Reactor Building is designed to be accessible 10 days before and 3 days after the outage

NRO = Normal Refueling Outage

Target: 16 days
ATMEA1™ Basic Design
External reviews

Dec-07 - Jun-08
IAEA review of conceptual design safety principles

Jun-10 - Aug-11
ASN review of the safety options against the French regulation

Jan-07 - Oct-07
Conceptual design

Nov-07 - Dec-09
Basic design

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ATMEA1™ Basic design
Regulatory and Safety Frameworks

- Designed with U.S. NRC regulations, U.S. industry consensus Codes and Standards and ICRP for radioprotection
- Compliant with IAEA Safety Standards
- Reviewed against the experience of Generation III+ AREVA’s EPR™ and MHI’s APWR (i.e. French, Finnish, Chinese, US and Japanese regulations)
- Reviewed against the French Regulatory regime
  - Laws (Orders of 13/10/2003, 31/12/1999…)
  - Guidelines
    - Applicable fundamental safety rules
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Main parameters

- FOAK or NOAK project
- Site Technical Data
- Contract specificities (contractual mode, scope, schedule)
  - Lead time, construction time
- Specific country regulations
- Localization (Industrial capability)
Project execution

- Adjust standard basic design requirements to the Project and re-do accordingly parts of Basic Design (Configuration Zero)

- Construction license

- Launch detailed design (sample of activities)
  - Define technical configuration strategy up to commercial operation
  - Adjust equipment specifications, launch manufacturing design
  - Safety studies: PSAR, PSA, FSAR
  - Systems design
  - I&C Hardware and Software design
  - Produce execution drawings
  - Integrate feedback from manufacturing design and equipment suppliers
  - Support to Construction and Commissioning
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- Long and ambitious venture
- Require large financial and resource investment
- Rely on an extensive pool of knowledge (mix of R&D, proven technology)
- Methods and tools are part of the success key
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