Overview of AREVA’s EPR™ Reactor

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EPR™ Development Goals

1. “Evolutionary design” to fully capitalize on the design, construction and operating experience based on the 86 AREVA's PWR operating worldwide.

2. Enhanced Safety compared to operating PWRs:
   - reduce core damage frequency (CDF),
   - accommodate severe accidents with no long-term population effect,
   - Withstand large airplane crash.

3. High availability

4. Simplified operation and maintenance.

5. Generation cost at least 10% lower than 1500 MWe series in operation.

► Improved investors, operators and community confidence
Joint Recommendations of French and German Safety Authorities (1993)

Three main objectives:

► Evolutionary rather than revolutionary design;
► Significant reduction of core meltdown probability and improvement of the reactor containment capability (also for severe accidents);
► Improvement of operating conditions:
  - radiation protection,
  - waste management,
  - maintenance,
  - reduction of human error risk

For the 1st time, 2 Safety Authorities combine their efforts to establish a common safety reference
Building on the Achievements of the N4 and Konvoi Reactors

**N4**
- High output (1475MWe)
- Large core (205 FA)
- High steam pressure (73,1 bar)
- Fuel building
- Computerized MCR
- Concrete cylindrical containment

**Konvoi**
- Military aircraft resistance
- 4 independent Safety trains
- No spray system
- Top mounted instrumentation

**EPR™ Design**
- Very High output: ~1600MWe
- Very large core: 241 FA
- Very High steam pressure: 77,2 bar
- Fuel building
- Computerized MCR
- Best-in-class APC resistance
- 4x100% independent Safety trains
- DBA: No spray system
- Top mounted instrumentation

The EPR™ design combines, and improves on, the best features of the French and German technologies.
## Main plant data

<table>
<thead>
<tr>
<th>Type of plants</th>
<th>N4</th>
<th>EPR™</th>
<th>KONVOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core thermal power (MWth)</td>
<td>4250</td>
<td>4590</td>
<td>3850</td>
</tr>
<tr>
<td>Electrical output (MWe)</td>
<td>1475</td>
<td>1660</td>
<td>1365</td>
</tr>
<tr>
<td>Number of loops</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>N° of fuel assemblies</td>
<td>205</td>
<td>241</td>
<td>193</td>
</tr>
<tr>
<td>Type of fuel assemblies</td>
<td>17x17</td>
<td>17x17</td>
<td>18x18</td>
</tr>
<tr>
<td>Active length (cm)</td>
<td>427</td>
<td>420</td>
<td>390</td>
</tr>
<tr>
<td>Total F.A. length (cm)</td>
<td>480</td>
<td>480</td>
<td>483</td>
</tr>
<tr>
<td>Rod linear heat rate (W/cm)</td>
<td>179</td>
<td>166,7</td>
<td>167</td>
</tr>
<tr>
<td>N° of control rods</td>
<td>73</td>
<td>89</td>
<td>61</td>
</tr>
<tr>
<td>Total flowrate (kg/s)</td>
<td>19420</td>
<td>22220</td>
<td>18800</td>
</tr>
<tr>
<td>Vessel outlet temp. (°C)</td>
<td>330</td>
<td>330</td>
<td>326</td>
</tr>
<tr>
<td>Vessel inlet temp. (°C)</td>
<td>292</td>
<td>295.2</td>
<td>292</td>
</tr>
<tr>
<td>S.G.: heat exch. Surface (m²)</td>
<td>7308</td>
<td>7960</td>
<td>5400</td>
</tr>
<tr>
<td>Steam Pressure (bar)</td>
<td>73</td>
<td>77</td>
<td>64.5</td>
</tr>
</tbody>
</table>
Basic Design Organization
(Up to early 2000 for the industrial organization - until end of 1998 for the involvement of the German Safety Authorities)

- Safety Experts
  - IPSN
- Advisory Groups
  - GPR
    - Groupe Permanent Réacteur
- Safety Authorities
  - Ministries of Industry and Environment
  - GRS
  - Joint Working Groups
    - Joint Meetings
  - RSK
    - Reactor Safety Commission
  - DFD F/G Directorate
- Customers
  - EDF
    - Electricité de France
  - EVU
    - German Utilities
- Engineering
  - EDF
    - French industry
    - CI
      - Overall
        - A/E
  - Siemens
  - Framatome
  - Siemens
  - Design Participation
  - Nuclear Island (NI)
  - NPI
  - CI
    - BOP
    - Overall
      - A/E

Slovakia - 15 September 2010  EPR™ Overview

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EPR™ Design Goals
Meeting Utilities Needs

- Decision of EDF and the German utilities in 1991 to join the EPR™ development
  - French and German utilities involved early in assessment of technical options

- EPR™ is designed to meet the European Utility Requirements (EUR)
  - Assessment first performed by utilities in 1999
  - Update of the assessment completed in 2009
EPR™ PLOT PLAN

1. Reactor Building
2. Fuel Building
3. The Safeguard Buildings
4. Diesel Buildings
5. Nuclear Auxiliary Building
6. Waste Building
7. Turbine Building
8. Circulating Water Pumps Building
9. Circulating Water Seal Pit
10, 11. Essential Water Pumps Building
12, 13. Service Water Collecting Pond

Legend:
- Train 10/50
- Train 20
- Train 30
- Train 40/80
- Concrete Channels for Essential Service Water System
- Nuclear Island
- Turbine Island
- Balance of Plant
Turbine Building OL3 Configuration

Two 2-stage reheaters

Steam from NI

Water to NI

Turbine Generator
overall length 67.1 m
Primary System with a 4-loop configuration is very close to existing designs

Main components enlarged as compared to those in operation to increase grace period in many transients and accidents

Extensive use of forgings with integral nozzles

Materials resistant to corrosion and cracking

Proven design components
Main flange and nozzle shell in one piece: less welds

Reduction of inspection time required for ISI

Low level of neutron flux on pressure vessel
Containment and Confinement

- **Double wall containment:**
  - Inner shell: pre-stressed concrete with a steel liner
  - Outer shell: reinforced concrete

- **Annulus between double-shell** is maintained at a sub-atmospheric pressure

- All leakages are collected in the annulus

- Filtration prior to stack release would further reduce radioactive aerosols
EPR™ Reactor, Fuel and two Safeguard Buildings are airplane crash resistant for both military and commercial aircraft:

- No licensing delay
- Bolstering public and political acceptance
**EPR™ Reactor Safety Systems: Protection of the environment with Passive and Active Systems**

### Passive System (Short-term)

1. Temporary retention in the reactor pit (gravity and metal gate)
2. Spreading in the large surface dedicated area (metal gate melting and gravity)
3. Flooding and cooling of the spreading area using IRWST (In-containment Refueling Water Storage Tank)

### Active System (Long-term)

1. Removal of containment heat:
   - Recirculation and coolant heat exchange
   - Containment spray system

- Optimum severe accident mitigation prevent releases of hazardous material into the atmosphere and/or the soil
Protection against internal hazards by divisional separation
**EPR™ Reactor Safety Systems: Diversified power source with back-ups**

Two independent grid connections to ensure power distribution diversity

4 independent safety divisions, 2 with additional SBO Diesel

**Diagram:**
- **Main grid** at 400kV
- **Stand-by grid** at 110kV
- Emergency power supply with interruption
- Uninterrupted Emergency power supply
Instrumentation, Control and Man-Machine Interface Systems

Up-to-date technologies for digital I&C and computerized man-machine interface systems

Substantial experience feed-back to enhance:

► Availability
  ◆ Limitation functions decrease the unplanned reactor trips frequency
  ◆ Design is fault-tolerant
  ◆ Periodic tests are executed during plant operation
  ◆ Detailed on-line diagnosis and modular structure allow corrective maintenance with minimum impact on plant operation

► Safety
  ◆ Design is tolerant to common cause failures by hardware and software diversity
  ◆ Optimized and simplified plant operation with guidance provided to operators
EPR™ Main Control Room
General view

SICS control desks and panels

Plant Overview Displays

Additional desk

Operators' desks

Shift Supervisor desk
EPR™ Optimized Generation Cost

1. Power level raised to 1600+ MWe
2. Steam cycle efficiency of 37% (steam pressure of 7.7 MPa)
3. Better fuel utilization
4. Maintenance simplification
5. Short refueling outages
6. Reduction of personnel irradiation doses
7. Plant life time duration of 60 years

7 measures resulting in generation cost per MWh ~ 10% lower than for French 1500 MWe series
EPR™ load-follow capability

► Usual load-follow: power level variation between 60% and 100% NP
  ◆ Return to 100 % NP possible at 5%/min during 80 % of the fuel cycle

► Unusual load-follow: low power level between 25% and 60% NP
  ◆ Return to 100 % NP possible at 2.5%/min during 80 % of the fuel cycle

► Extended operation at intermediate power level is possible without restriction neither on the duration nor on the power level
  ◆ For less than 2 days of operation at intermediate power level, no additional restriction on load flexibility
  ◆ For more than 2 days, additional constraints for returning to full power are accepted

► EPR™ reactor operating at intermediate power level must contribute to the spinning reserve by its capability of rapid return to full power
Licensing Achieved or under Way in 5 Countries

- In September 2004, the French Safety Authorities stated that the safety options of the EPR™ reactor met the safety enhancement objectives established for new reactors.


- US NRC design certification expected 3rd Q 2011, rulemaking in 2012; first COL (Calvert Cliffs) in 2012.

- First reactor subjected to the Multinational Design Evaluation Program (MDEP) applied by US NRC, ASN (France), STUK (Finland) and NNSA (PRC). This sets favorable framework for EPR licensing in other countries.
The AREVA Reactor Range
The AREVA Reactor range

GEN III+ KEY BENEFITS

- Maximized availability: design target >92%
- Short outages
- High thermal efficiency
- Minimized global power generation costs
- Low O&M costs
- Fuel cycle flexibility
- MOX fuel

BUSINESS PERFORMANCE

OUTSTANDING SAFETY

- Large commercial Airplane Crash resistance (APC)
- Advanced severe accident management
- Optimized level of redundancy, diversity of systems and incremental mitigation of abnormal events

ENVIRONMENTAL PROTECTION

- Minimal environmental impact
- Reduced collective dose

ENERGY SUPPLY CERTAINTY

- GenIII+ evolutionary designs
- AREVA integrated supply chain strategy for critical components
- Proven Digital Safety I&C technology
- Maximized standardization for simplified licensing
AREVA is the only player with a Gen III+ reactor range

- The reference in Safety
- Answer the varied customer needs with an adapted product portfolio

AREVA’s reactor range

- BWR 1250 MWe
  - Medium Power Output
  - Boiling Water Reactor
  - Market launch: 2010
  - Deployed

- PWR 1100 MWe
  - High Power Output
  - Pressurized Water Reactors

- PWR 1650 MWe
  - Developed in partnership with MHI
  - Market launch: 2010
  - Deployed
The ATMEA1™ Reactor

The mid-sized GenIII+ PWR

- Generation III+ PWR
  - 3-Loop
  - 2 860 - 3 150 MWth
  - SG pressure 71b at 100% power
  - 3x100% redundancy of active systems, passive safety systems and an additional backup cooling chain
  - Backup in case of total loss of safety function

- Medium power output (1 100 MWe)
- Evolutionary design based on the EPR™ and MHI’s APWR
- Outstanding safety level
- Minimal environmental impact

Strong customer interest from GDF Suez
The KERENA™ Reactor

The mid-sized GenIII+ BWR

- Generation III+ BWR
  - 3 370MWth
  - Steam pressure 75b at 100% power
  - Diversity and redundancy of safety systems:
    - 2 active safety systems
    - 4 passive safety systems

- Medium power output (1 250 MWe)
- Design based on successful operation experience in the latest German BWRs
- Outstanding safety level
- Minimal environmental impact

Strong customer interest from E.ON
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