Generation III of nuclear reactors

Generation III

The nuclear reactors technology

Summary of the generation III of nuclear reactors technology

Actual status of realization

Ing. Martin Titka, AREVA NP Controls, Bratislava
for Young Generation at NUSIM 2008 in Častá Papiernička

This figures are not authorized by AREVA.
All data have been compiled from official sources like internet by the author.
Enhanced safety (4 safety trains, core catcher, protection against aircraft crash…)
Enhanced construction (modular systems, new technology)
Simplification and optimization of System/Equipment design and construction
Digital I&C
Enhanced economical aspects…
Perspective for New Nuclear Plants

Nuclear reactors

- **PWR**: EPR (AREVA), AP 1000 (Westinghouse), VVER 1200 (ASE), APR 1400 (Doosan), APWR (MHI)
- **LWR**: VBER 300 (ASE), VVER 1000 (ASE), CNP-1000 (CNNC), CPR-1000 (CGNPC), CNP-600 (CNNC)
- **BWR**: ABWR (GE, Hitachi), ESBWR (GE), AB 1600 (Toshiba), SWR 1000 (AREVA)
- **HWR**: ACR 1000 (AECL)

Indian Department of Atomic Energy
Generation III of nuclear reactors

Generation III

The nuclear reactors technology
(Pressurized Water Reactors)

Summary of the generation III of nuclear reactors technology

Actual status of realization
**EPR — European (Evolutionary) pressurized water reactor**

**Overview**

> **Large evolutionary PWR reactor**

> **Approximate electric capacity up to 1600 MWe (4 loops)**

> **Designed by Framatome and Siemens, nowadays being a part of AREVA**

> **Derived of French N4 plants (1450 MWe) and German KONVOI plants (1365 MWe)**

**Design features**

> **four 100% capacity trains of engineered safety features**

> **double-walled containment, APC – protection to aircraft crashes**

> **“core catcher” for cooling of core materials after severe accidents, e.g. failure of reactor vessel**

> **design does not rely on only passive safety**

> **can use also mixed-oxide fuel (MOX)**

> **In any case there is no need for evacuation of people living around**
Overview

- Advanced Passive 1000 (PWR reactor)
- Approximate electric capacity 1154 MWe (2 loops)
- Designed by Westinghouse
- Derived from the AP 600, with strictly limited modifications

Design features

- Uses the forces of nature and simplicity of design to enhance plant safety and operations and reduce construction costs
- Passive systems are used for core cooling, containment isolation and containment cooling
- Main Control Room Emergency Habitability System
Overview

- Advanced VVER 1200 (PWR reactor)
- Approximate electric capacity 1160 – 1200 MWe (4 loops)
- Designed by Rosatom (ASE)
- Derived from the VVER 1000 V-320 and is essentially an advanced version of the V-428.

Design features

- System consists of four completely independent trains with capacity 4x33.3% (horizontal steam generators)
- System functioning is based on “passive” principles. System design ensures completely independent operation without operator’s intervention for at least 24 hours. For the period from 24 to 72 hours the design provides for mobile equipment and reserve water supplies.
Overview

- Advanced pressurized water reactor 1400 (PWR reactor)
- Approximate electric capacity 1400 MWe (2 loops)
- Designed by Dosam (KHNP)
- Derived from the OPR1000 and basis System 80+.

Design features

- Pseudo 2-loop arrangement, with two very large Steam Generators loops (2 hot-legs, 4 cold-legs, 2 SGs)
- Passive design features
- Prefabrication and modularization
Overview

> **Advanced pressurized water reactor (PWR reactor)**

> **Approximate electric capacity 1538 MWe (EU-APWR and US-APWR 1700 MWe) (4 loops)**

> **Developed by Mitsubishi Heavy Industries and Westinghouse**

> **Derived from the Japan PWRs.**

Design features

> **The safety systems have enhanced redundancy, utilizing 4 trains each capable of supplying 50% of the needed makeup water instead of 2 trains capable of 100%.

> **The core is surrounded by a neutron reflector which increases reactivity and saves ~0.1wt% U-235 enrichment**

> **Fuel can be used MOX**

> **The improvements in this passive system have led to the elimination of the Safety Injection system, an active system.**
Generation III of nuclear reactors

Generation III

The nuclear reactors technology
(Boiling Water Reactors)

Summary of the generation III of nuclear reactors technology

Actual status of realization
Overview

- **Advanced boiling water reactor ABWR**
- **Approximate electric capacity 1350 MWe**
- **Designed by General Electric (cooperation Hitachi and Toshiba)**
- **Derived from the best BWR design features from Europe, Japan, and US.**

**Design feature**

- **Reactor internal pumps** – improved safety and performance by eliminating external recirculation systems
- **Optimized module designs** refined and proven in real installations
- **Sophisticated control systems** – fully digital, providing reliable and accurate plant monitoring, control and diagnostics
- **Integrated containment and reactor building** – improved seismic response, compact and easier to construct
Overview

> **Economic Simplified Boiling water reactor (BWR reactor)**
> **Approximate electric capacity 1550 MWe**
> (4 pipes for steam + 2 for feed water – no pumps)
> **Designed by General Electric and Hitachi**
> **Derived from the ABWR and SBWR.**

**Design features**

> **Cut construction and operating cost significantly from earlier ABWR designs.**
> **Natural circulation during normal operation and elimination of recirculation pumps. Condenser system has four passive independent high-pressure loops**
> **Passive safety systems (gravity-driven cooling system 72 hours without operator action, passive containment cooling system)**
> **Reductions in building volumes**
> **Standardized construction design**
Generation III of nuclear reactors

Generation III

The nuclear reactors technology

(Heavy Water Reactor)

Summary of the generation III of nuclear reactors technology

Actual status of realization
Overview

> Advanced CANDU Reactor – evolutionary class pressure tube reactor, light-water-cooled, heavy-water-moderated
> Approximate electric capacity 1200 MWe (4 loops)
> Designed by Atomic Energy of Canada Limited (AECL)
> Derived from the CANDU 6.

Design features

> The ACR-1000 retains basic CANDU design features such as: modular, horizontal fuel channel core, low-temperature heavy water moderator, water-filled vault, two diverse shutdown systems, on-power fuelling and an accessible reactor building for on-power maintenance.
> Reduction in heavy water inventory by approximately 60% over traditional CANDU
> Ability to burn alternate fuels such as mixed oxides (MOX) and thorium
> Enhanced power manoeuvring ability due to a lower xenon load after shutdown than in traditional CANDU plants
Generation III of nuclear reactors

Generation III

The nuclear reactors technology

Summary of the generation III of nuclear reactors technology

Actual status of realization
## Comparison of features

<table>
<thead>
<tr>
<th>Developer</th>
<th>EPR</th>
<th>AP1000</th>
<th>VVER1200 AES 1200</th>
<th>APR1400</th>
<th>APWR</th>
<th>ABWR</th>
<th>ESBWR</th>
<th>ACR 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Capacity Net (MWe)</td>
<td>AREVA</td>
<td>WH / Mitsubishi</td>
<td>Rosatom</td>
<td>KHNP</td>
<td>Mitsubishi</td>
<td>Hitachi / Toshiba / GE</td>
<td>GE</td>
<td>AECL</td>
</tr>
<tr>
<td>Design Life (Year)</td>
<td>1600~1700</td>
<td>1100</td>
<td>1160</td>
<td>1,400</td>
<td>1538~1700</td>
<td>1700</td>
<td>1560</td>
<td>1085</td>
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<tr>
<td>Construction Period (Months)</td>
<td>60</td>
<td>60</td>
<td>50</td>
<td>60</td>
<td>48</td>
<td>46</td>
<td>48</td>
<td>35</td>
</tr>
<tr>
<td>Efficiency %</td>
<td>37</td>
<td>35.6</td>
<td>36.2</td>
<td>35</td>
<td>34.5</td>
<td>38</td>
<td>34.7</td>
<td>36.6</td>
</tr>
<tr>
<td>Enrichment U-235</td>
<td>Up to 5% / MOX</td>
<td>3.3-5%?</td>
<td>first fuel cycles with different U-235 enrichments</td>
<td>&lt;5% / MOX</td>
<td>&lt; 5%</td>
<td>4.2%</td>
<td>Low-enrichment UO2 1.5-2% (MOX)</td>
<td></td>
</tr>
<tr>
<td>Core Damage Frequency (RY)</td>
<td>less 1xE-6</td>
<td>2.5xE-7</td>
<td>1xE-7</td>
<td>2.46xE-6</td>
<td>less 1xE-5</td>
<td>1.6xE-7</td>
<td>2xE-7</td>
<td>Less 3.4xE-7</td>
</tr>
</tbody>
</table>

*The data given here are available on homepage of manufacturers*
Generation III - technology summary

this is a personal summary elaborated by the author
Generation III of nuclear reactors

Generation III

The nuclear reactors technology

Summary of the generation III of nuclear reactors technology

Actual status of realization
Actual status

EPR (AREVA)

- Operation
- Plans COL in US
- Under construction
- Plans

- Olkiluoto 3
- Flamanville 3
- Taishan 1&2
AP 1000 (Westinghouse)

- Haiyang 1&2
- Sanmen 1&2

- Operation
- Plans COL in US
- Under constructions
- Plans
VVER-1200/V-491 AES-2006 (AES)
Actual status

APR 1400 (DOSAM)

- Shin-Kori 3&4
- Shin Ulchin 1&2

Legend:
- Operation
- Plans COL in US
- Under constructions
- Plans
Actual status

APWR (MHI & Westinghouse)

- Comanche Peak - Texas 1&2
- Tsuruga 3&4

- Operation
- Plans COL in US
- Under constructions
- Plans
Actual status

ABWR (GE & Hitachi & Toshiba)

- South Texas 3&4
- Kashiwazaki-Kariwa 6&7
- Shimane 3
- Hamaoka-5

Legend:
- Green: Operation
- Red: Plans COL in US
- Yellow: Under constructions
- Orange: Plans
Actual status

ESBWR (GE & Hitachi)

- Operation
- Plans COL in US
- Under constructions
- Plans
Actual status

ACR-1000 (AECL)

- Operation
- Plans COL in US
- Under constructions
- Plans

New Brunswick Power
<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Licensing</th>
<th>Plans</th>
<th>Realization or signet contracts</th>
</tr>
</thead>
<tbody>
<tr>
<td>VVER-1200</td>
<td>Russia China? India? Europe?</td>
<td>Russia <strong>9. planned in Leningrad II -110/2008 17 – proposed in Russia</strong></td>
<td><strong>1 units in Russia</strong> 4/2007 Novovoronezh II – 1 under construction</td>
</tr>
<tr>
<td>APWR</td>
<td>Fully-verified and under licensing in Japan and the US</td>
<td>Japan <strong>2 units</strong> Tsuruga 3&amp;4 start operation in 2014 &amp; 2015 <strong>US 2 units</strong> Comanche Peak - Texas</td>
<td>-</td>
</tr>
<tr>
<td>ABWR</td>
<td>licensed in Japan, Taiwan, and application in the U.S COL.</td>
<td><strong>2 units in US South Texas 3&amp;4</strong> 6 units in Japan China?</td>
<td>Japan <strong>3 units are operating</strong> Hamakaa-6 from 1/2005 Kashiwazaki-Kariwa-8 &amp; 11/1996 7/1998 <strong>1 unit under construction Shimane 3, start operation 12/2011</strong></td>
</tr>
<tr>
<td>ESBWR</td>
<td>Submitted to the US NRC for design approval and subsequently COL application in UK</td>
<td><strong>5 units in US</strong> Victoria 1&amp;2, River Bend 2, Grand Gulf 2 North Anna 3</td>
<td>-</td>
</tr>
<tr>
<td>ACR-1000</td>
<td>Application in Canada, UK, US</td>
<td>Canada <strong>1 unit</strong> New Brunswick Power</td>
<td>-</td>
</tr>
<tr>
<td>VVER-1000</td>
<td></td>
<td>Tianwan <strong>2 units</strong> (units 1 &amp; 2) China AES91</td>
<td>India <strong>2 units</strong> Kudankulam 1&amp;2 Iran <strong>1 units</strong> Bulgaria <strong>2 units</strong> Belene V-466</td>
</tr>
</tbody>
</table>
**Actual status**

**Number of units**

*real / planned*
Thank you for your attention

Discussion