MITSUBISHI US-APWR

Overview

June 29, 2007
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2. Development of US-APWR
3. US-APWR main Concept
4. Key Design Features
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8. Deployment Organization
9. Conclusions
1. What is US-APWR

**US-APWR** satisfies U.S. customers requirements with the best performance for **Safety**, **Economy**, **Operation**, and **Maintenance**!
1. What is US-APWR (cont’d)

- **US-APWR** design is based on Japanese APWR.

- New technologies of APWR are fully tested, well-verified and established.

- **US-APWR** is slightly modified
  - to increase electric output
  - to comply with the U.S. regulations
  - to meet the U.S. utilities requirements
The First APWRs (Tsuruga3/4)

- First Concrete Pouring Date: October, 2010
- Commercial Operation
  - Unit 3: 2016
  - Unit 4: 2017
APWR’s advanced technology

**Reactor**
- 1500 MWe class large capacity
- Neutron reflector

**Steam Generator**
- High performance separator
- Increased capacity with compact sizing

**I & C**
- Digital control & protection systems
- Compact console

**Engineering Safety Features**
- Simplified configuration with 4 mechanical sub-systems
- In-containment RWSP
- Advanced accumulator

**Turbine**
- 54 inch-length blades in LP turbine
- Fully integrated LP turbine rotor

- Low Pressure Turbine
- Generator
- High Pressure Turbine

- SH SH
- RWSP RV
- ACC ACC
- ACC ACC
- CSP CSP
- CSP CSP
- SIP SIP
- SIP SIP
## Verifications for Advanced Designs

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<th>1995</th>
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<td>Reactor Internals and Neutron Reflector</td>
<td>Performance Tests</td>
<td>Flow Tests</td>
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<td>Compact SG and Improved Separator</td>
<td>Performance, Flow, Seismic Tests</td>
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<tr>
<td>Advanced Accumulator</td>
<td>Performance Tests</td>
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<td>High-performance RCP</td>
<td>Performance and Flow Tests</td>
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<td>Advanced I&amp;C System</td>
<td>Operability Tests with Simulator</td>
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<tr>
<td>Turbine</td>
<td>Performance and Vibration Tests</td>
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</table>
2. Development of US-APWR

US-APWR is developed to consider with the following items:

- Correspondence to electric power demand increase in the U.S.
- Comply with U.S. regulations
- Meet the U.S. Utilities requirements such as URD
3. US-APWR main concepts

Evolutionary (not "Revolutionary") Design

- Similar to standard 4-loop PWR design currently in operation in the U.S.
- Based on APWR design currently under licensing process in Japan
- Fully verified new technologies to enhance safety, reliability, economy and operability
Enhanced Safety

- A four-train safety systems for enhanced redundancy
- An advanced accumulator
- An in-containment refueling water storage pit

Core Damage Frequency

- Current Four-loop PWRs
- US-APWR

1
2 x 10^{-2}
Enhanced Reliability

- A stem generator with high corrosion resistance
- A neutron reflector with improved internals

A 90% reduction in plant shutdowns compared to other 4-loop PWRs
Attractive Economy

- A large core with a thermal efficiency of 39%
- Building volume per MWe that is four-fifths that of other 4-loop PWRs

![Graph showing comparison of uranium consumption, thermal efficiency, and building volume per MWe between Current Four-loop PWRs and US-APWR.]
More Environmentally Friendly

- A 28% reduction in spent fuel assemblies per MWh compared to other four-loop PWRs
- Reduction occupational radiation exposure
- Capacity to use mixed oxide (MOX) fuels made from reprocessed nuclear fuel waste
Improved Operability

- Fully digital control and protection systems

- Large Display Panel
- Operator Console
- Conventional HSI
- Alarm VDU
- Operation VDU (Non-Safety)
- Safety VDU
Comparison of Output & Main Components

<table>
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<tr>
<th></th>
<th>U.S. Current 4 Loop</th>
<th>APWR</th>
<th>US-APWR</th>
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<tr>
<td>Electric Output</td>
<td>1,180 MWe</td>
<td>1,538 MWe</td>
<td>1,700 MWe Class</td>
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<tr>
<td>Core Thermal Output</td>
<td>3,411 MWt</td>
<td>4,451 MWt</td>
<td>4,451 MWt</td>
</tr>
<tr>
<td>Steam Generator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>54F</td>
<td>70F-1</td>
<td>91TT-1</td>
</tr>
<tr>
<td>Tube size</td>
<td>7/8”</td>
<td>3/4”</td>
<td>3/4”</td>
</tr>
<tr>
<td>Reactor Coolant Pump</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>93A-1</td>
<td>100A</td>
<td>100A</td>
</tr>
<tr>
<td>Turbine</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>LP last-stage blade</td>
<td>44 inch</td>
<td>54 inch</td>
<td>70 inch class</td>
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</table>

**APWR**

- 1538 MWe output is achieved by large capacity core and large capacity main components such as SG, RCP, turbine, etc.

**US-APWR**

- 1700 MWe class output is achieved from a 10% higher efficiency than APWR.
  - Same core thermal output with APWR
  - High-performance, large capacity steam generator
  - High-performance turbine
## Comparison of Fuel, Core & Internals

<table>
<thead>
<tr>
<th></th>
<th>U.S. Current 4 Loop</th>
<th>APWR</th>
<th>US-APWR</th>
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<tbody>
<tr>
<td>Core Thermal Output</td>
<td>3,411 MWt</td>
<td>4,451 MWt</td>
<td>4,451 MWt</td>
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<tr>
<td>NO. of Fuel Assem.</td>
<td>193</td>
<td>257</td>
<td>257</td>
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<tr>
<td>Fuel Lattice</td>
<td>17 x 17</td>
<td>17 x 17</td>
<td>17 x 17</td>
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<tr>
<td>Active Fuel Length</td>
<td>12ft</td>
<td>12ft</td>
<td>14 ft</td>
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<td>Reactor internals</td>
<td>Baffle/former structure</td>
<td>Neutron Reflector</td>
<td>Neutron Reflector</td>
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<tr>
<td>In-core Instrumentation</td>
<td>Bottom mounted</td>
<td>Bottom mounted</td>
<td>Top mounted</td>
</tr>
</tbody>
</table>

### APWR
- ✔ Large capacity core by increasing number of fuel assemblies
- ✔ Installation of neutron reflector to enhance reliability and fuel economy

### US-APWR
- ✔ Low power density core using 14ft. fuel assemblies with the same reactor vessel as APWR to enhance fuel economy for 24 months operation
- ✔ Enhanced reliability and maintainability of reactor vessel by top mounted ICIS
## Comparison of Systems, CV and I&C

<table>
<thead>
<tr>
<th>Safety Systems</th>
<th>U.S. Current 4 Loop</th>
<th>APWR</th>
<th>US-APWR</th>
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<tbody>
<tr>
<td>Trains</td>
<td>2 trains</td>
<td>2 trains</td>
<td>4 trains</td>
</tr>
<tr>
<td>Mechanical</td>
<td>2 trains</td>
<td>4 trains</td>
<td>4 trains</td>
</tr>
<tr>
<td>HHSI pump</td>
<td>100% x 2</td>
<td>50% x 4(DVI)</td>
<td>50% x 4(DVI)</td>
</tr>
<tr>
<td>LHSI pump</td>
<td>100% x 2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ACC</td>
<td>4</td>
<td>4 (Advanced)</td>
<td>4 (Advanced)</td>
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<tr>
<td>RWSP</td>
<td>Outside CV</td>
<td>Inside CV</td>
<td>Inside CV</td>
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### I & C

<table>
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<tr>
<th>Containment Vessel</th>
<th>U.S. Current 4 Loop</th>
<th>APWR</th>
<th>US-APWR</th>
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</thead>
<tbody>
<tr>
<td>Control Room</td>
<td>Conventional</td>
<td>PCCV</td>
<td>PCCV</td>
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<tr>
<td>Safety I&amp;C</td>
<td>Conventional</td>
<td>Full Digital</td>
<td>Full Digital</td>
</tr>
<tr>
<td>Non-Safety I&amp;C</td>
<td>Full Digital</td>
<td>Full Digital</td>
<td>Full Digital</td>
</tr>
</tbody>
</table>

#### APWR
- Enhanced safety by simplified and reliable safety systems
  - Mechanical 4 train systems with direct vessel injection design
  - Elimination of LHSI pump by utilizing advanced accumulators
  - Elimination of recirculation switching by In-containment RWSP

#### US-APWR
- Enhanced safety by 4 train safety electrical systems
- Enhanced on line maintenance capability
4. Key Design Features
Fuel

- Low power density core using 14ft. FAs for 24 months operation
- Higher Density Pellet (97%T.D.)
- Grid Fretting Resistant Design (Shorter Span Length with 11 grids & Grid Spring Design)
Reactor Vessel

- Core thermal output: 4,451MWt
- 14 feet fuel length
- RV size is same as APWR
- Eliminate the bottom mounted ICIS
Steam Generator

- High Performance Separator
- Increased Capacity with Compact Sizing
- High Corrosion Resistance Tubes

Secondary separators
Primary separators
Anti-vibration bars
U-tubes
Reactor Coolant Pump

- Improved Hydraulic performance
- Advanced Seal
  - Improved Seal Characteristic and Durability
Turbine Generator

➢ Higher Efficiency
  • Two Stage Reheat MSR High Efficiency Reaction Blades

➢ Higher Reliability
  • Integral Shroud LP End Blade - ISB Monoblock LP Rotor
Advanced Accumulator

- Automatic switching of injection flow rate by flow damper
- Integrated function of low head injection system
- Long accumulator injection time allows more time for safety injection pump to start
Gas Turbine Generator for EPS

- Gas-Turbine Generators are applied to the Emergency Power Source
- Gas-Turbine Topical Report will be submitted NRC by the end of 2007

- The Gas Turbine is a very simple rotating engine with few components
- A water cooling system is not required
Gas-Turbine Generators also are applied to the Alternate AC power source.

- Gas-Turbine Generators of AAC are provided different type (Starting System, Capacity etc.) from Gas-Turbine Generators of EPS to minimize the potential for the common mode failure.
Robust and reliable Pre-stressed Concrete Container Vessel with steel liner is applied to US-APWR
RWSP

- RWSP is installed inside containment vessel
- Easy to meet the GSI-191 because the surface area of strainer can be increased easily
Countermeasure of SA

- **US-APWR achieves higher safety to comprehensively address severe accident and mitigate consequences**
  
  ✔ Demonstrate compliance with current NRC regulations including TMI requirements for new plants

  ✔ Demonstrate technical resolution of the applicable unresolved safety issues (USI), and the medium and high-priority generic safety issues (GSI) discussed in NUREG-0933
Countermeasure of SA (cont’d)

- RCS depressurization valve (4), (5)
- Igniter (1)
- Hydrogen monitor (1)
- Large dry containment (1), (7)
- Alternative containment cooling (7)
- Firewater pump
- Water storage tank
- Containment water injection (7)
- CS/RHR Hx
- CS/RHR pump
- SI pump
- Upgrade rating of RHR piping
- Igniter (1)
- Firewater injection to reactor cavity (2), (4), (6)
- Reactor cavity depth (2)
- Core debris trap (4)
- Debris spreading area (2), (6)
- Liner plate covering concrete (6)
- Drain line to reactor cavity (2), (4), (6)
- Emergency feed water pump
- Main steam relieve valve
- Turbine bypass valve
- DOE Technical Session
- UAP-HF-07062-29
Arrangement of Main Power Block

- Reactor Building (R/B)
- Turbine Building (T/B)
- Auxiliary Building (A/B)
- Access Control Building (AC/B)
- Gas Turbine Building (GT/B)
## 5. Key Plant Parameters

<table>
<thead>
<tr>
<th></th>
<th>APWR</th>
<th>US-APWR</th>
</tr>
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<tbody>
<tr>
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<td>Core Thermal Output</td>
<td>4,451 MWt</td>
<td>4,451 MWt</td>
</tr>
<tr>
<td>Core</td>
<td>12 ft Fuel 257 Assem.</td>
<td><strong>14 ft Fuel</strong> 257 Assem.</td>
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<tr>
<td>SG Heat Transfer Area per SG</td>
<td>70,000 ft(^2)</td>
<td><strong>91,500 ft(^2)</strong></td>
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<tr>
<td>Thermal Design Flow rate per loop</td>
<td>113,000 GPM</td>
<td>112,000 GPM</td>
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<tr>
<td>Turbine</td>
<td>54 inch blades</td>
<td><strong>70 inch class blades</strong></td>
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<td>Containment Vessel</td>
<td>PCCV</td>
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<td>Safety Systems</td>
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<td>Mechanical 4 trains</td>
<td>Mechanical 4 trains</td>
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<td></td>
<td>HHSI x 4</td>
<td>HHSI x 4</td>
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<tr>
<td></td>
<td>Advanced Accumulator x 4</td>
<td>Advanced Accumulator x 4</td>
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<td></td>
<td>Elimination of LHSI</td>
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<td>I&amp;C</td>
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<td>Full Digital</td>
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6. Submittal of DC and COL

- DC will be submitted at December in 2007
- COL will be submitted at December in 2008
- First Concrete will be poured at October in 2012

![Diagram]

(Notes) F/C: First Concrete
US-APWR Design Process and Time-line

Pre-Application Review (PAR) Phase

DCD Review Phase (after DCD submittal)

Construction Phase

Standard Design Completion

Topical Reports

DCD

Technical Reports

NRC audit

DCA

12/2007

6/2009

Draft SER

Expected around 12/2009

(<42 months after DCA)

DC

Expected prior to 6/2011

(Fuel Loading)

Construction

R-COL Application review

COLA

Docketed by NRC

Draft SER

Expected 9 months before Final SER

(<42 months after COLA)

COL

Final SER

Expected one year before COL

Draft SER

Expected around 9/2010

Final SER

Expected 9 months before Final SER

Final SER

Expected one year before COL

Draft SER

Expected around 12/2009

(<42 months after DCA)
## Submittal Plan of TR during PAR

<table>
<thead>
<tr>
<th>Category</th>
<th>Topical Report to be referred in DCD</th>
<th>Submittal Date</th>
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<tr>
<td>Quality Assurance (Ch. 17)</td>
<td>Quality Assurance Program Description for Design Certification of the US-APWR</td>
<td>January 2007</td>
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<td>ESF (Ch.6)</td>
<td>Advanced Accumulator</td>
<td>January 2007</td>
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<td>I &amp; C (Ch. 7)</td>
<td>Safety System Digital Platform –MELTAC-</td>
<td>March 2007</td>
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<td>I &amp; C (Ch. 7)</td>
<td>Defense-in-Depth and Diversity</td>
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<td>HFE (Ch. 18)</td>
<td>HSI System Description and HFE Process</td>
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<td>Reactor (Ch. 4)</td>
<td>Fuel System Design Criteria and Methodology</td>
<td>May 2007</td>
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<td>Accident Analyses (Ch. 15)</td>
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<td>Accident Analyses (Ch. 15)</td>
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## Submittal Plan of Technical Reports during DCD Application Review

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<th>Category</th>
<th>Technical Reports to be referred in DCD</th>
<th>Submittal Date</th>
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<tr>
<td>SSCs (Chapter 3)</td>
<td>Emergency Power Building design result</td>
<td>Dec. 2008</td>
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<td>Reactor Internal stress summary report</td>
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<td>Pressurizer surge line stress summary report</td>
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<td>MS line stress summary report</td>
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<tr>
<td>Fuel Assemblies (Chapter 4)</td>
<td>Fuel Assemblies design evaluation summary report for seismic and postulated accidents</td>
<td>June 2009</td>
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<td>RV (Chapter 3&amp;5)</td>
<td>Reactor Vessel stress summary report</td>
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<tr>
<td>Electric Power (Chapter 8)</td>
<td>Gas turbine generator design, qualification and test plan report</td>
<td>Nov. 2007</td>
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<tr>
<td>PRA (Chapter 19)</td>
<td>PRA Level 3 result (already discussed in 5th PAR in Mar. 2007)</td>
<td>Mar. 2008</td>
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The first DCWG was held on June 19th in 2008
The Reference COLA (R-COLA) is Comanche Peak #3,4
The subsequent COLAs (S-COLA) are expected by new utilities
7. QA

QA policy for DC application

QA program complies with:

- 10 CFR 50 Appendix B and the additional guidance of Standard Review Plan NUREG-800 Section 17.5

- ASME NQA-1-1994
  - PART I, including supplements with clarifications and exceptions proposed by NEI
  - PART II Subpart 2.7 “Quality Assurance Requirements of Computer Software for Nuclear Facility Applications”
7. QA (cont’d)

- SRP section 17.5 allows QAP to be submitted for both DC and COL, or separately
- MHI has established QAP for DC Application
- QAP for COL Application is under developing

**Diagram:**

- Schedule
  - DC
  - COL
- Application
  - QAP
  - QAP (under developing)
Structure of QA Documents on US-APWR Project

LEVEL 1
- QA Program

LEVEL 2
- QA Manual

LEVEL 3
- Standards & Procedures in each Dept./Sec.

QA Program for US-APWR
- N-Center QA Manual
  - Document Control
  - Design Control
  - Design Interface Control
  - Design Verification Control
  - Computer Software Control
  - Qualification Procedure of personnel responsible for management of the implementation of the QAP
  - Procurement Control
  - Control of Nonconformance
  - Corrective Action
  - Control of QA Record
  - Audits etc.

Dept. / Sec. Standards & Procedures
- Control of Computer Software Code and Verification Control
- Qualification & Certification Procedure of Lead Auditor
- Auditor Qualification Procedure, etc.
8. Deployment Organization

At the DC Stage

- NRC
- MNES
- APWR Promoting Dept. MHI Headquarters
- MHI Nuclear Engineering Center

Support of DCD Preparation

Project Control

Design and Preparation of DCD

MNES: Mitsubishi Nuclear Energy Systems, Inc.
MHI: Mitsubishi Heavy Industries, Ltd.
8. Deployment Organization (con’t)

After the DC Stage

US Electric Company

MNES

NRC

AE Company

APWR Promoting Dept.
MHI Headquarters

MHI
Nuclear Engineering Center

MHI
Kobe

MHI
Takasago

MELCO

MNES: Mitsubishi Nuclear Energy Systems, Inc.
MHI: Mitsubishi Heavy Industries, Ltd.
MELCO: Mitsubishi Electric Corporation

Civil, Building, BOP and construction

Main Contractor and Project Control

Project Control of MHI

Design and Manufacturing of NI Components and Fuel

Design and Manufacturing of TI Components

Design and Manufacturing of I&C and Electrical Equipment

Planning and Basic Design of NI and TI
9. Conclusion

- US-APWR design is based on Japanese APWR and is modified to meet the U.S. utility's requirements
- US-APWR is 1700MWe class large NPP and high performance efficiency
- US-APWR is currently under PAR stage. DCD will be submitted in the end of 2007 and also COLA will be docketed in the end of 2008