Current Status related to Operating NPPs in Korea

(Safety Enhancement Activities Through PSR and Stress Test)

2017. 2

Tae Eun JIN
1. NPP Status in Korea and KEPCO E&C

- **Operation (25), Construction(5), Schedule(6)**
  - WEC Type: 6 units
  - CANDU Type: 4 units
  - Framatome Type: 2 units
  - CE Type: 8 units
  - OPR1000: 4 units
  - APR1400: 1 unit
  - APR1400: 5 units (Under Construction)
  - UAE: 4 units (Under Construction)

- **Hanul**
  - #1~6
  - #1~2 (Shin)

- **Wolsong**
  - #1~4
  - #1~2 (Shin)

- **Kori**
  - #1~4
  - #1~3 (Shin)
  - #4~6 (Shin)

- **Hanbit**
  - #1~6
1. NPP Status in Korea and KEPCO E&C

- Founded in Oct. 1, 1975
- Employee: 2,226 (Jun. 30, 2016)
- Major Business Areas
  - NSSS Design of NPP
  - BOP Design and AE of NPP
  - Design of Thermal Power Plant and Renewable Energy System
  - R&D in Plant Engineering
- Currently Designing
  - 5 Domestic NPPs (Shinkori 3~6, Shinhanul 1~2)
  - 4 Foreign NPPs (UAE)
Major Projects Executed
Nuclear Projects (Design 31 units out of a total of 34)

<table>
<thead>
<tr>
<th>Number of units</th>
<th>APR+ 1)</th>
<th>Under development</th>
<th>Making an exclusive brand for core technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>APR1400 (Advanced Power Reactor 1400)</td>
<td>Shin-Kori 5, 6</td>
<td>Applying the secured nuclear power plant technologies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UAE 1-4</td>
<td>Securing global competitiveness</td>
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<tr>
<td></td>
<td></td>
<td>Shin-Hanul 1, 2</td>
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<tr>
<td></td>
<td></td>
<td>Shin-Kori 3, 4</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>OPR+2)  (Improved Optimized Power Reactor)</td>
<td>Shin-Wolsong 1, 2</td>
<td>Enhancement of design engineering technology</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shin-Kori 1, 2</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>OPR1000 (Optimized Power Reactor)</td>
<td>Hanul 5, 6</td>
<td>Self-sufficiency in design engineering technology (1995)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hanbit 5, 6</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Hanul 3, 4</td>
<td>Introducing technology and promoting its independence</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>Hanbit 3, 4</td>
<td>Depending on foreign design engineering</td>
</tr>
<tr>
<td>12</td>
<td>Kori 1, 2, 3, 4 / Hanbit 1, 2 / Hanul 1, 2 / Wolsong 1, 2, 3, 4</td>
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</tr>
</tbody>
</table>

* Kori Unit 1, 2 and Wolsong Unit 1 - performed by other companies
## Thermal Power Projects (Design 57 units)

<table>
<thead>
<tr>
<th>Number of units</th>
<th>Developing next-generation thermal power technologies (sophisticating steam conditions)</th>
<th>Under development</th>
<th>High-efficiency of the future</th>
</tr>
</thead>
<tbody>
<tr>
<td>57</td>
<td>1000MW KSFP Construction</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Goseong Units 1, 2</td>
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<td></td>
<td></td>
<td></td>
<td>Gangneung Units 1, 2</td>
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<td></td>
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<td></td>
<td>Shinseocheon Plant</td>
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<td>Pos Power Units 1, 2</td>
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<td>Taean Units 9, 10</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Shin Boryeong Units 1, 2</td>
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<td></td>
<td>Samcheok Units 1, 2</td>
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<td></td>
<td>Dangjin Units 9, 10</td>
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<tr>
<td>38</td>
<td>Upgraded 800MW KSFP</td>
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<tr>
<td></td>
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<td>Yeongheung Units 1, 2</td>
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<td>Yeongheung Units 3, 4</td>
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<tr>
<td>34</td>
<td>Improved 500MW KSFP Design</td>
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<td></td>
<td>Boryeong Units 7, 8</td>
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<td>Hadong Units 7, 8</td>
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<td>Dangjin Units 7, 8</td>
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<td>Taean Units 7, 8</td>
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<td>Dangjin Units 5, 6</td>
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<tr>
<td>24</td>
<td>500MW KSFP Construction</td>
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<td></td>
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<td></td>
<td>Samcheonpo Units 5, 6</td>
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<td>Dangjin Units 3, 4</td>
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<td>Hadong Units 5, 6</td>
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<td>Taean Units 5, 6</td>
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<td>Hadong Units 1, 2, 3, 4</td>
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<td>Taean Units 1, 2, 3, 4</td>
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<td>Samcheonpo Units 3, 4</td>
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<tr>
<td>4</td>
<td>Boryeong Units 3, 4, 5, 6</td>
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</tr>
</tbody>
</table>

*Under construction (500MW): Bukpyeong units 1, 2 / Dangjin Eco power units 1, 2

**Under construction (19 Units):**
- Goseong Units 1, 2
- Gangneung Units 1, 2
- Shinseocheon Plant
- Pos Power Units 1, 2
- Taean Units 9, 10
- Shin Boryeong Units 1, 2
- Samcheok Units 1, 2
- Dangjin Units 9, 10

**Under operation (40 Units):**
- Yeongheung Units 1, 2 / Yeongheung Units 3, 4
- Boryeong Units 7, 8 / Hadong Units 7, 8
- Dangjin Units 7, 8 / Taean Units 7, 8
- Dangjin Units 5, 6
- Samcheonpo Units 5, 6 / Dangjin Units 3, 4 / Hadong Units 5, 6 / Taean Units 5, 6
- Hadong Units 1, 2, 3, 4 / Dangjin Units 1, 2
- Taean Units 1, 2, 3, 4 / Samcheonpo Units 3, 4

**Enhancing economic feasibility and heat efficiency:**

**Ultra super critical pressure thermal power generation:**

**Introducing technology and promoting its independence (1995):**

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KEPCO E&C
2. Periodic Safety Review

Definition

- A systematic safety reassessment of an operational NPP carried out at regular intervals to deal with the cumulative effects of plant ageing, modifications, operating experiences and technical developments, and aimed at ensuring a high level of safety throughout the plant service life.

- Comprehensive safety evaluation for operational nuclear power reactors in accordance with 14 safety factors IAEA recommended per every 10 years

PSR Implementation Guide

- Nuclear Act, Enforcement Regulation No. 20, 21

2. Periodic Safety Review

- 11th NSSC legislative meeting (Dec. 1999)
  - Adopting PSR initiative for domestic operating NPPs safety review and its enhancement

- PSR Pilot Application for Kori Unit 1 (2000)

- Establishment of PSR framework by amending Nuclear Safety Act (Jan. 2001)
  - Revision for enforcement ordinance chapter 36, 37, 38 (timing, contents, criteria) & enforcement regulation 20, 21 (details and criteria) (Jul. 2001)
  - Regulation on first PSR implementation time for nuclear facilities (Jan. 2002)

- Apply PSR to fleet wide NPPs (2002~ )
3. Implementation Results of PSR

- **1st Round PSR for 20 NPPs that have been operating more than 10 years have been completed.**
  - Westinghouse Type: Kori 1,2,3,4, Hanbit 1,2
  - Framatome Type: Hanul 1,2
  - CE Type: Hanbit 3,4,5,6, Hanul 3,4,5,6
  - PHWR: Wolsung 1,2,3,4

- **2nd Round PSR for 3 NPPs are currently being carry out**
  - Kori 2
  - Hanbit 5,6
3. Implementation Results of PSR

**Transient Evaluation (Ex.)**

<table>
<thead>
<tr>
<th>No.</th>
<th>Transient Type</th>
<th>Number of Cycle at Design Documents</th>
<th>Review Operation Experience in PSR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Actual Number of Cycles</td>
<td>Life Expenditure (%)</td>
</tr>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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<td>3</td>
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<td>...</td>
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</tbody>
</table>

→ On the basis of transients counting results during last 10 yrs operation, transient evaluation results showed the fatigue integrity of the pressure boundary components for the next 10 yrs.
3. Implementation Results of PSR

**Approaches**
- Review the ISI reports
- Review the long term ISI plan

**Review Results**
- Re-confirm and Check the Effectiveness of ISI Results and findings for the SSCs
- Also, CNF and related corrective activities for each outage were reviewed and checked.
3. Implementation Results of PSR

**Approaches**

- Review of NRC Generic Documents and Industry LR Application Documents

<table>
<thead>
<tr>
<th>NRC Generic Document</th>
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<tr>
<td>o Generic Letter &amp; Bulletin</td>
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<tr>
<td>o Information Notice</td>
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<table>
<thead>
<tr>
<th>License Renewal Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>o LRA Report : Total 81 Units (As of 2016. 8)</td>
</tr>
<tr>
<td>o GALL Rev.2(‘10. 12), NEI 95-10 Rev. 6</td>
</tr>
</tbody>
</table>

**Review Results(ex.)**

- Proactive measure based on U.S. operating reactor operating experience to reflect and apply to domestic NPPs
- Ex) Westinghouse type reactor internals GTSP replacement

→ Replace entire Inconel X-750 materials with those made of 316 stainless steel
3. Implementation Results of PSR

- Identification of Safety Improvement Action Items and Its Implementation

→ Nuclear utilities should implement PSR safety improvement action items and report implementation status to KINS every quarter in accordance with approved plan and schedule.

Source: Yun Bongyo et., 2010.11
4. Stress Test

- **Objective of Stress Test**

  - Stress Test aims to strictly reconfirm the safety of NPP by evaluating its capability to respond to large-scale natural disasters beyond the design basis.
4. Stress Test

- Evaluation areas are mainly the following 5 areas.
  - Safety of SSCs against Earthquakes
  - Safety of SSCs against Tsunami, Storm Surge, and Other Natural Disasters
  - Plant Response to Loss of Electrical Power and or Loss of the Ultimate Heat Sink
  - Severe Accident Management Capability
  - Emergency Preparedness and Response

- Status of Stress Test Implementation
  - Complete for Wolsung 1 and Kori 1 in 2013~2015
  - Plan to perform for all other units in Korea (2016~)
5. Implementation Results of Stress Test

✔ Safety Improvements of SSCs against Earthquakes, Tsunami, Storm Surge, and Other Natural Disasters

- Implementation of seismic margin analysis for equipment of Spent Fuel Pool Cooling System
- Implementation of seismic margin analysis for replaced equipment related to safe shutdown function
- Reinforcement of Action Procedures to take when earthquake occurs at NPP
- Improvements of onsite suppression capability for seismic induced wide area fire
- Installation of water-tight doors
- Safety review of slope against earthquake beyond the design basis
- Reinforcement of on-site fire brigade building against earthquake beyond the design basis
5. Implementation Results of Stress Test

- Safety Improvements against loss of electrical power and the ultimate heat sink & Severe accident management
  - Installation of Mobile Generator & secure stable operation ability for MG
  - Installation of mobile water pump
  - Installation of external injection paths for the primary and secondary side & Spent fuel pool
  - Enlargement of batteries
  - Securement of communication tools between field operators and MCR or RSP (on-site satellite telephone)
  - Reinforcement of procedure and training program for operator
  - Reinforce the habitability of OSC, TSC
6. Earthquake in Gyeongju

Earthquake

- The Gyeongju earthquake near Wolsong site occurred on Sep.12, 2016.
- Measuring 5.8 on the moment magnitude scale, it was the strongest ever recorded in Korea since measurements begun in 1978.
- Fore-S: Sep. 12 19:44 (Mag 5.1), Gyeongbuk, Gyeongju, SouthernSE 9km
- Main-S: Sep. 12 20:32 (Mag 5.8), Gyeongbuk, Gyeongju, SouthernSE 8km
6. Earthquake in Gyeongju

- Earthquake
  - After-Shock Status: (Mag. > 1.5, Sep. 19 till 20:33): Totally 380
6. Earthquake in Gyeongju

- Seismic tasks and CounterMeasures (5 tasks, 22 CMs)
  - Evaluation and reflection of earthquake disaster near NPP
    - Promotion of capable fault investigation through governmental department
    - Formulation of nuclear design reflection procedure in case of a new fault detection (e.g. case in US)
    - Earthquake effect evaluation in Gyeongju
    - Analysis of domestic earthquake and geological characteristics
  
  - Acceleration of countermeasures for seismic performance
    - Main facility, watertight doors, etc. for NPP safety
    - Stress Tests implementation and facility reinforcement
    - Performance improvement of earthquake monitoring equipment
    - Formulation of seismic performance evaluation methodology
6. Earthquake in Gyeongju

- Enhancement of emergency response capability
  - Construction of the seismic isolation structure for emergency
  - Installation of rapid response organization of severe accident
  - ...

- Continuous evaluation and enhancement of earthquake countermeasure
  - Cooperation enhancement of the United States, Japan, etc.
  - ...

- Long-term improvement of NPPs safety
  - Development of next-generation NPP for innovative safety improvement
  - Installation of earthquake response research center
  - Information portal, information disclosure ...
# Decommissioning

## Korean Licensing Status (Operation vs Decom. : draft)

<table>
<thead>
<tr>
<th>Work</th>
<th>Operating License</th>
<th>Operating License</th>
<th>Operating License</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operation</strong></td>
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</tr>
<tr>
<td><strong>Transition Period</strong></td>
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<td></td>
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</tr>
<tr>
<td><strong>Year</strong></td>
<td>1  2  3  4  5  6</td>
<td>7  8  9  10  11  12</td>
<td>13  14</td>
</tr>
<tr>
<td>Permanent Shutdown</td>
<td></td>
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<tr>
<td>Fuel Transport from Rx to SFP</td>
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<tr>
<td>Fuel Transport from SFP to ISFSI</td>
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<tr>
<td>Approval of Decom Plan (DP)</td>
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<tr>
<td>Licensing of DP</td>
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<tr>
<td>Preparatory Work for Decom.</td>
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<tr>
<td>Decommissioning Work</td>
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<tr>
<td>Site Restoration</td>
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<tr>
<td>Approval of License Termination</td>
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</tbody>
</table>

*Note: Diamond icons indicate key milestones.*
SSCs modification in Decommissioning

- System Disconnection
  - Disconnection between necessary system and unnecessary system
  - Mark-up on drawings with step-by-step physical disconnection
  - Ex) disconnection of primary system (unnecessary during decommissioning) etc

Deionatsystem RY
- TF40 Z701 ZB0214: Deionatnachspeiseleitung (DN 80) RY → TF40
  Verschluss durch Grenzarmatur TF40 S037 und Kunststoffkappe
  TF40 S037/O38 verbleiben als Störkante im Cluster.
**PSR during Decommissioning**

- **Needs during decommissioning phase?**
  - PSR shall be required for operating systems during decommissioning phase such as spent fuel cooling system including interface systems (CCWS etc.)
  - In 2018, PSR shall be implemented because operating license of Kori unit 1 is still effective after permanent shutdown on 18th June, 2017 nevertheless approval of decommissioning license.
  - In PSR, unnecessary systems such as primary systems of RCS, CVCS, etc. can be deleted according to the amended Defueled Safety Analysis Report (DSAR) for permanent shutdown.
  - In some countries, PSR is generally required as long as spent fuel is in the plant. Once the spent fuel is removed a PSR is no more needed for plant itself. However then the intermediate fuel storage and/or the storage of intermediate and low level radioactive waste have to undergo specific PSRs.
7. Lessons Learned

- Implementation of PSR safety improvement action items contributed to enhancement of safety improvement efforts by site personal and understanding of safety culture, and thus resulted in maintaining higher level of safety.

- As results of PSR implementation to countermeasure cumulative effects of plant aging, sound framework for plant safety management have been well established.

- Through PSR, it is expected that plant personal can organize the operating data systematically and reflect operating experience continuously.

- Based on the Stress Test experience with Kori 1 and Wolsung 1, it can be concluded that NPPs are safely operated against large-scale natural disasters beyond the design basis and Stress Test will be implemented for all the other NPPs for nuclear safety enhancement.
Nuclear Safety First, Last and Always

Thank You!