In-Service Inspection for Multiple Type NPPs in China

Honghao Ouyang

Director of International Business
China Nuclear Power Operation Technology Corporation, LTD. (CNPO)
1. Overview for NPP in China mainland
2. Requirement and strategy for ISI
3. General ISI technologies for NPPs
4. Specific ISI technologies for NPPs
5. ISI Experience for Multiple Type NPP
6. Conclusion
1. Overview for NPP in China mainland

<table>
<thead>
<tr>
<th>Units</th>
<th>Province</th>
<th>Net capacity (each)</th>
<th>Operator</th>
<th>Commercial operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daya Bay 1&amp;2</td>
<td>Guangdong</td>
<td>944 MWe</td>
<td>CGN</td>
<td>1994</td>
</tr>
<tr>
<td>Qinshan Phase I</td>
<td>Zhejiang</td>
<td>298 MWe, 1020 MWe</td>
<td>CNNC</td>
<td>April 1994</td>
</tr>
<tr>
<td>Qinshan Phase III, 1&amp;2</td>
<td>Zhejiang</td>
<td>678 MWe</td>
<td>CNNC</td>
<td>2002, 2003</td>
</tr>
<tr>
<td>Fangjiashan 1,2</td>
<td>Zhejiang</td>
<td>1020 MWe</td>
<td>CNNC</td>
<td>Dec 2014, (Feb 2015)</td>
</tr>
<tr>
<td>Ling Ao Phase I, 1&amp;2</td>
<td>Guangdong</td>
<td>938 MWe</td>
<td>CGN</td>
<td>2002, 2003</td>
</tr>
<tr>
<td>Ling Ao Phase II, 1&amp;2</td>
<td>Guangdong</td>
<td>1026 MWe</td>
<td>CGN</td>
<td>Sept 2010, Aug 2011</td>
</tr>
<tr>
<td>Tianwan 1&amp;2</td>
<td>Jiangsu</td>
<td>990 MWe</td>
<td>CNNC</td>
<td>2007, 2007</td>
</tr>
<tr>
<td>Ningde 1,2,3,4</td>
<td>Fujian</td>
<td>1020 MWe</td>
<td>CGN &amp; Datang</td>
<td>April 2013, May 2014</td>
</tr>
<tr>
<td>Hongyanhe 1,2,3</td>
<td>Liaoning</td>
<td>1024 MWe</td>
<td>CGN &amp; CPI</td>
<td>June 2013, May 2014,</td>
</tr>
<tr>
<td>Yangjiang 1,2,3</td>
<td>Guangdong</td>
<td>1021 MWe</td>
<td>CGN</td>
<td>March 2014,</td>
</tr>
<tr>
<td>Fuqing 1,2,3</td>
<td>Fujian</td>
<td>1020 MWe</td>
<td>CNNC &amp; Huadian</td>
<td>Nov 2014</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>30 units</strong></td>
</tr>
</tbody>
</table>

**Up to Feb. 2016, 30 units in operation, 24 units Under construction, and about 40 units Planned.**
## Application codes/standards and characterization for NPPs

<table>
<thead>
<tr>
<th>Units</th>
<th>ISI Code and standard</th>
<th>Main characterizations of NPPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daya Bay 1&amp;2</td>
<td></td>
<td>Examination system of RPV and SG is very similar as the PWR NPPs applying with ASME. Only NDT tech. are little different, and manipulators will be modified according to the different NPPs. Specially, for example, examination system and technology for RPV BMI and the seal welds of CRDM.</td>
</tr>
<tr>
<td>Qinshan Phase II, 1&amp;2</td>
<td>RSE-M 1997</td>
<td></td>
</tr>
<tr>
<td>Qinshan Phase II, 3&amp;4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fangjiashan 1&amp;2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ling Ao Phase I, 1&amp;2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ling Ao Phase II, 1&amp;2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ningde 1,2,3,4,5,6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hongyanhe 1,2,3,4,5,6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yangjiang 1,2,3,4,5,6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuqing 1,2,3,4,5,6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qinshan Phase III, 1&amp;2</td>
<td>CAN/CAS</td>
<td>The pressure Tube is very different from the RPV of PWR NPPs. Specially, thickness Measurement for CANDU feeder pipe and Video Examination for Support and Hanger of Feeder Pipe</td>
</tr>
<tr>
<td>Tianwan 1,2,3,4</td>
<td>Russian code</td>
<td>For horizontal Steam Generator, the special SG ET system has been used during ISI</td>
</tr>
<tr>
<td>Qinshan Phase I</td>
<td>ASME 1998</td>
<td>For AP1000, Specially, examination system and technology for the weld of RCP to SG nozzle of AP1000 and RPV DVI</td>
</tr>
<tr>
<td>Sanmen 1,2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haiyang 1,2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. Requirement and Strategy for ISI

The different type NPPs comply with different PSI/ISI code

Codes and standards used for NPP:

- French RSE-M(RCC-M)
- USA ASME
- Russia standards
- Canadian standards

For example, different examination scope, periodic, sampling and NDT technology/equipment for the different type NPPs.
2. Requirement and Strategy for ISI

- The strategy of ISI for multiple type reactor in China:
  - To analyze the structure characteristic, application codes and requirement of ISI for all type NPP
  - To R & D the different NDT equipment and to use the specific NDT technologies to satisfied ISI requirement for different type NPPs
  - To keep the NDT data acquisition system is same or similar for different type reactor, i.e. UT and ET instrument, and software
2. Requirement and Strategy for ISI

- To keep some NDT equipments (manipulators), main parts are same or similar
- To manufacture the different mockup NPP for function testing and training
- To prepare different ISI program for different NPPs
3. General ISI Technologies for NPPs
3. General ISI Technology for NPP

3.1 Examination system and technology for Reactor Pressure Vessel

a) Scope of examination: Shell weld, nozzle weld and safe-end weld
b) Technology: Contact ultrasonic, RT and remote Video Exam
c) Manipulator: CRUS/SUPREEM

CRUS examination system for RPV
3. General ISI Technology for NPP

1) For shell and nozzle welds: detection by 45T2, 60T2, 70TRL probes, sizing by high frequency longitudinal wave probe (i.e. 45L4, 45TRL4)

2) For safe-end welds: UT (45TRL and 70TRL) & RT examination

3) For flange thread area: UT (0L2+45T2) examination

SUPREEM examination system for RPV
3. General ISI Technology for NPP

3.2 Examination system and technology for Steam Generator tubes

ET

a) Scope of examination: whole length for 100% tubes
b) Technology: Bobbin, MRPC, Array probe
c) Equipment: “BEEBOT” probe fixture, “CEddy” data acquisition and analysis software system
3. General ISI Technology for NPP

- For whole tube: Bobbin probe, MRPC probe for retesting
- For expansion: MRPC or array probe
3.3 Examination system and technology for Piping welds

a) Scope of examination: weld and head-affected zone

b) Technology:

• For ferrite piping welds: UT examination - detection by transverse wave probe, sizing by longitudinal wave probe.

• For austenite piping welds: UT examination - longitudinal wave probe for welds, transverse wave probe for head-affected zone.

c) Equipment: AUMA manipulator for different pipe size
3. General ISI Technology for NPP

3.4 Examination system and technology for Upper Closure Head Penetration of Nuclear Reactor Vessel

a) Scope of examination: the “J” groove welds of CRDM
b) Technology: ET for the surface of welds, UT for the whole volume of welds (TOFD + Pulse Echo)
c) Equipment: CHEAS machine
3. General ISI Technology for NPP

3.5 Examination system and technology for RCCA

a) Scope of examination: defect types including swelling, wear and crack.

b) Technology: immersion focusing UT probe and Eddy current external probe

c) Equipment: RAID machine
3.6 Examination system and technology for RPV Stud and Nut

a) Scope of examination: screw region for ET, whole volume for UT
b) Technology: Ultrasonic immersion transducers and eddy current pencil probes
c) Equipment: STAR machine
4. Specific ISI technology for NPP
4.1 ISI Technology for M310

1) Examination system and technology for RPV BMI

a) Scope of examination: penetration nozzle and heated affected zone.

b) NDT Technology:
   a) Immersion focusing Ultrasonic transducer, Eddy current bobbin and rotating probe
   b) ET is used for the inner surface of penetration nozzle
   c) UT is used for the nozzles and welds between nozzle and vessel.
4.1 ISI Technology for M310

**UT Technology:**
1. axial/circ. TOFD
2. S45°
3. L21°

**ET technology:**
1. MRPC for detection
2. Bobbin for sizing
4.1 ISI Technology for M310

2) Examination system and technology for fail fuel rod assemblies
   a) Scope of examination: fuel tube
   b) NDT Technology: the lamb wave UT, Through to checking if there is the water in the tube to confirm the leakage condition of it
   c) Equipment: FUMA manipulator
3) Examination system and technology for the seal welds of CRDM
   a) Scope of examination: seal weld and base material in upper, middle and down part welds
   b) Technology: water immersion focusing ultrasonic transducer and Eddy current array probe
4.1 ISI Technology for M310

**UT technology:**

**Axial examination:**
1) Frequency: >10MHz, shear wave,
   Angle: 35~40°
2) T-R transducer:
   Frequency: >10MHz, longitudinal wave,
   Angle: 44°.
3) TOFD transducers

**Circumferential examination:**
1) T-R transducer: Frequency: >10MHz,
   shear wave, Angle: 45°

**ET Examination:**
Two types of ET Probe are used to the examination
1) Cross Winded (CW) probe is for detection
2) Parallel Coil (PC) probe is for depth measurement
4.2 ISI Technology for AP1000

1) Examination system and technology for the weld of RCP to SG nozzle of AP1000
   a) Scope of examination: 1/3 inner thickness of welds
   b) Technology: scanning from ID, the dual element longitudinal wave probes (TRL) are used for UT, due to the casting austenite material of pipe.
4.2 ISI Technology for AP1000

2) Ultrasonic examination system and technology of AP1000 RPV DVI

a) Scope of examination: safe-end welds and heated affected zone
b) NDT Technology: the water immersion transducers are used for UT
4.3 ISI Technology for WWER1000

1) Examination system and technology for WWER1000 SG tube ET
   a) Scope of examination: whole length tubes and collector ligaments
   b) Technology: Bobbin, MRPC probe
   c) Equipment: CEMA manipulator
1) Thickness Measurement for CANDU feeder pipe
   a) Scope of examination: bend area of feeder pipe
   b) Technology: to use the high frequency ultrasonic (phased array imaging tech.)

CANDU heat transfer feeder pipe position
The inspection scope of Feeder pipe
The inspection condition of Feeder pipe
4.4 ISI Technology for CANDU600

2) Video Examination for Support and Hanger of Feeder Pipe
   a) Scope of examination: integrity for pipe support and hanger
   b) Technology: remote video examination
   c) Equipment: FVIS machine
1) UT examination for RPV
   a) Scope of examination: weld of vessel
   b) Technology: UT examination from outside, detection by transverse wave transducers, and sizing by higher frequency longitudinal wave transducers
4.6 ISI Technology for CEFR

1) Remote field ET for SG tubes
   a) Scope of examination: 100% tubes
   b) Technology: remote field eddy current testing
5. ISI Experience for Multiple Type NPP

For RPV examination

- Requirement and characterization of RPV examination:
  - Different code and standard
  - Examination Time limitation
  - Different acceptance criteria

- Recent application and resolving method
  - Little different of manipulator used for different RPV, i.e. different support legs
  - Control unit and software are same
  - Same UT instrument and data treatment software
  - Similar UT transducers, for defect detection and sizing
  - Different recording level, i.e. diameter 2mm SDH for RSE-M and ASME, diameter 3.1mm FBH for Russia Code
5. ISI Experience for Multiple Type NPP

- Multiple scanning platform, i.e. scanning for different welds in same time
- In the future, pulse echo UT + Phased array UT
5. ISI Experience for Multiple Type NPP

- For SG tubing ET
  - Requirement and characterization of SG tubing ET:
    - Different code and standard
    - Different structure of SG, i.e. PWR and WWER
  - Recent application and resolving method
    - BEEBOT/Pegasys for PWR, CEMA for WWER
5. ISI Experience for Multiple Type NPP

- BOBBIN + MRPC Eddy current probe
- Different calibration tubes, i.e. ASME calibration tubes or RSE-M calibration tubes for relative codes
- Automatic Data Acquisition, and remote data analysis (In Wuhan, out of the NPP sites)

- In the future, array probe will be used roundly
- And also, Automatic data analysis technology will apply to the SG tubing Eddy current examination
5. ISI Experience for Multiple Type NPP

- For Stainless Steel Pipe Welds UT
  - Requirement and characterization of pipe weld UT:
    - NDT technology shall be qualified
    - A-scan UT is difficult for sizing of defects during qualification
    - High reliability UT technology is required
  - Recent application and resolving method
    - Automatic pulse echo UT
      - Use the auto manipulator (AUMA)
      - Multiple channel ultrasonic instrument (pulse echo UT)
    - Manually Phased Array ultrasonic examination technology for SS pipe weld UT
5. ISI Experience for Multiple Type NPP

- For ISI NDT qualification of multiple type NPP by different code
  - Basically, RSE-M methodology has been used for NDT qualification in China
  - ISI applications are divided to three type qualification, i.e. general, conventional, and specific qualifications
  - To include technical justification (TJ) and experiment trial
  - For ASME code NPP, specific qualification shall be according to the Appendix VIII of ASME XI
6. Conclusion

- For the different NPPs, the some new special tools and technology will be used for specific component or parts. For example:

<table>
<thead>
<tr>
<th>Reactor TYPE</th>
<th>Typical difference technology for ISI</th>
</tr>
</thead>
<tbody>
<tr>
<td>M310</td>
<td>Some special NDT technologies and equipment such as BMI</td>
</tr>
<tr>
<td>AP1000</td>
<td>Special tool applying to RCP for AP1000</td>
</tr>
<tr>
<td>WWER1000</td>
<td>Special tools for horizontal SG tubes ET.</td>
</tr>
<tr>
<td>CANDU</td>
<td>Remote Video Examination for Support and Hanger of Feeder Pipe</td>
</tr>
<tr>
<td>HTR</td>
<td>RPV inspection from outside of vessel because of unreachable from inside</td>
</tr>
</tbody>
</table>
6. Conclusion

- The most of general ISI technologies can be used for different type NPPs, and just only adjust some NDT parameters and relative tools.
Thanks for your attention!