Overview of In service inspection for nuclear power plants in China

Authors: Liang Ge, Yong Nie, Yuanhuan Xu, Honghao Ouyang, Jiafan Cai

China Nuclear Power Operation Technology Corporation, LTD (CNPO)
Contents

1. Brief Introduction
2. Application of ISI in NPP
3. Inspection Qualification of ISI
Part 1 Brief Introduction

- Layout of NPPs in China
- Type of different Reactors
- Laws and Rules of ISI by Regulator
- ISI vendors
1.1 Layout of NPPs in China

17 units in service

26 units on construction

25 units in preparation
1.2 Type of different Reactor

- **Native Technology**
  - CP300
  - CP600
  - CPR1000
  - CNP1000
  - HTR-PM

- **French Technology**
  - M310
  - EPR

- **Canadian Technology**
  - CANDU

- **Russian Technology**
  - VVER

- **USA Technology**
  - AP1000
1.3 Laws and Rules of ISI by Regulator

According to the requirements of the national nuclear safety administration (NNSA), China nuclear standards are divided into three levels.
1.3 Laws and Rules of ISI by Regulator

The Atomic Energy law

- The fundamental law of nuclear energy
- Legal basis for the formulation of laws, regulations, and rule
- Defines the policy of basic requirements, safety and quality of nuclear industry development
1.3 Laws and Rules of ISI by Regulator

**NNSA Rules**

- The supervision management regulations for the design and manufacture installation and non-detective test of the civil nuclear safety equipment (HAF601) ISI vendors have to get the certification granted by Regulator according to HAF601.

- Management regulations on the qualification of NDT personnel of the civil nuclear safety equipment (HAF602) NDT personnel have to get the certification granted by Regulator according to HAF602.
1.3 Laws and Rules of ISI by Regulator

ASME
- Qinshan No.1 NPP
- Sanmen NPP
- Haiyang NPP
- ---

RSE-M
- Qinshan No.2 NPP
- Daya Bay NPP
- Lingao NPP
- Hongyanhe NPP
- ---

CAN/CAS
- QS No.3 NPP

ПИАЭГ
- Tianwan NPP
1.4 ISI vendors

Presently, there are three in-service inspection vendors for nuclear power plants in China.

- Longest history of services
- Most advanced technology
- Largest market share (60%)
Part 2. Application of ISI in NPP

Application

Mandatory ISI by Code

Other ISI by experience feedback
2.1 Mandatory ISI by Code

- ISI of RPV
- ET of heat transfer tubes of Steam Generator (SG)
- Thickness measure for CANDU Feeder Pipe
- Other automatic inspection
- Manual inspection

- NDT of RPV studs and nuts
- UT for pipe weld
- UT for equipment weld
- UT, RT, VT, PT, MT
2.1 Mandatory ISI by Code

NDT of RPV shell welds and nozzle Welds

- RPV automatic inspection machine
- Different kinds of UT Probes with multi-channel digital data collecting devices and visible data analysis software
2.1 Mandatory ISI by Code

Reactor Pressure vessel inspection system (SUPREEM)

- Applied to CP600 type reactor.
2.1 Mandatory ISI by Code

Reactor Pressure vessel inspection system (MIS 3)

• Applied to CP300 and VVER type reactor.
Reactor Pressure Vessel special inspection tools (ZUMA & ZRMA)

- ZUMA is used for UT inspection on the safe end welds of RPV nozzles
- ZRMA is used for RT inspection on the safe end welds of RPV nozzles

2.1 Mandatory ISI by Code
2.1 Mandatory ISI by Code

ET of heat transfer tubes of Steam Generator (SG)

- The inspection system includes SM22, multi-frequency eddy current instrument, data acquisition and analysis workstation, probe positioner, probe pushing-drawing system, monitoring and communication systems.
- Applied to PWR and CANDU
2.1 Mandatory ISI by Code

ET of heat transfer tubes of Steam Generator (SG)

- PEGASYS of SG Eddy Current Inspection System
- Applied to AP1000 and other PWR
2.1 Mandatory ISI by Code
2.1 Mandatory ISI by Code

Thickness measure for CANDU Feeder Pipe

- Methods: Ultrasonic Testing (UT)
2.1 Mandatory ISI by Code

Inspection of RPV studs and nuts

- **Studs**: ET is used for thread area, and UT is used for full volume testing.
- **Nuts**: Point eddy current probe is used for the inspection of thread area.
2.1 Mandatory ISI by Code

Inspection of welds on other main equipment and pipes

- Other main equipment in nuclear island includes steam generator, pressurizer, main pump and etc. for which the girth welds are tested by UT usually.
- UT and RT are usually used for volume testing of welds in nuclear pipes.
2.2 Other ISI by experience feedback

- NDT of rod cluster control assembly (RCCA)
- NDT of Sealing Welds on Control Rod Driving Mechanism (CRDM)
- NDT of RPV head and bottom penetrations
- Fuel assembly deformation measurement
- Phase array inspection for Turbine blade Root
- NDT of Reactor pressure vessel Thimble tubes
2.2 Other ISI by experience feedback

## Inspection of RCCA

- **Scope & Contents:** Swelling, Crack and Wear of control rods.
- **Methods:** Combination of Ultrasonic Testing (UT) and Eddy Current Testing (ET).
2.2 Other ISI by experience feedback

NDT of Sealing Welds on Control Rod Driving Mechanism (CRDM)

- Scope & Contents: full volume testing of sealing weld
- Methods: combination of Ultrasonic Testing (UT) and Eddy Current Testing (ET)
- Equipment: remote control automatic inspection machine
2.2 Other ISI by experience feedback

ISI of RPV head and bottom penetrations

• Scope: Outer surface & fusion zone of J groove weld, penetration body.
• Methods: combination of Ultrasonic Testing (UT), Eddy Current Testing (ET) and Surface Testing.
• Equipment: remote control automatic inspection machine
2.2 Other ISI by experience feedback

Fuel assembly deformation measurement

- Scope: Fuel assembly framework
- Methods: Ultrasonic Testing (UT),
- Equipment: remote control automatic inspection machine
Part 3. Inspection Qualification of In-Service Inspection for NPP in China

1. Applied Qualification Approach in China
2. Qualification Application in China
3. Inspection qualification for qinshan III (CANDU)
3.1 Applied Qualification Approach in China

● NNSA serves as Qualification Body

● The ISI/PSI technology must be qualified in all units of NPPs in China as long as their ISI codes comply with ASME or RSEM which contains the requirement of qualification

● Qualification approach in China

➢ Qualification approach: ENIQ
  ✓ TJ, Non-blind trials, Blind trials

➢ Qualification classification: refer to RSE-M (97), including ASME Qualification (AP1000)
  ✓ Conventional Qualification
  ✓ General Qualification
  ✓ Specific Qualification
  ✓ Not requiring Qualification
3.1 Applied Qualification Approach in China

Classification method (Refer to RSEM)
3.1 Applied Qualification Approach in China

Qualification method

- **Specific Qualification**
  - Review the document (Inspection specification, Procedure, TJ, functional testing report, etc.)
  - Functional testing of equipment or tools on-site
  - Non-Blind trial
  - Blind trial

- **General Qualification**
  - Review the document (Inspection specification, Procedure, TJ, functional testing report, etc.)
  - Functional testing of equipment or tools on-site
  - Non-Blind trial

- **Conventional Qualification and No requiring Qualification**
  - Review the document (Inspection specification, Procedure)
3.1 Applied Qualification Approach in China

**Qualification method**

- **Qualification followed as ASME (Specific Qualification)**
  - Pieces designed as ASME
  - Acceptance Standard of Qualification follows as ASME
  - Technique justification
  - ENIQ Methodology

- **Qualification result can be shared between the similar designed units**
  - Same code
  - Similar examined components
  - Same inspection technique
  - No need to qualify again while reviewing of all the documents by NNSA
3.2 Qualification Application in China

Qualification application began from 2009 in China

Stage 1: 2009
Stage 2: 2010
Stage 3: 2011-present
3.2 Qualification Application in China

Stage 1 in 2009

- No qualification body was founded that time
- RSE-M (97) is applied in Qinshan 2 NPP
- Qualification is mandatory
- Specific Qualifications were performed in UK-IVC
- Other qualification were carried out by an inspection company in the monitoring of NNSA
3.2 Qualification Application in China

Stage 1 in 2009

- **Items qualified in UK-IVC**
  - UT of RPV shell welds (including cladding)
  - UT of RPV Nozzle to shell welds
  - UT of RPV safeend DMW welds
  - UT of RPV safeend to piping welds
3.2 Qualification Application in China

Stage 1 in 2009

- Using ENIQ guidelines
  - Written Technical Justifications
  - Procedure Qualification Trials – in blind trials at UK IVC
  - Data Acquisition Engineer Qualifications – demonstrations at UK IVC
  - Data Analysis Engineer Qualification Trials – in blind trials on data collected during Procedure Trials, at UK IVC and CNPO
  - Equipment Functional Tests – in practical demonstrations using PSI equipment on full scale mock-ups at CNPO
3.2 Qualification Application in China

Stage 1 in 2009

- All Inspection Procedures have been successfully qualified to meet the requirements of the RSEM 97 Code for UT PSI/ISI of Qinshan 2 Units 3 & 4
- Additional qualifications have been obtained for the detection and sizing of transverse defects in the nozzle to safe end and safe end to pipe welds
3.2 Qualification Application in China

Stage 2 in 2010

- Lingao NPP Units with RSE-M (97)
- Qualification of CITEC inspection technique performed by CNPO (Qualified by UK-IVC)
- NNSA monitored all processes
- ENIQ Approach
- RSEM classification
3.2 Qualification Application in China

**Stage 2 in 2010**

- **Specific Qualification (Lingao 3/4 NPP)**
  - RT of RPV nozzle to safeend welds
  - UT of RPV nozzle to safeend welds
  - UT of RPV shell welds
  - UT of bond between Cladding and Metal base of RPV
  - ET of Steam Generator Tubes (Data acquisition and Data Analysis)

- **General Qualification (Lingao 3/4 NPP)**
  - UT of RPV Nozzle safeend to piping welds
  - CCTV of RPV internal surface of shell cladding
  - UT of RPV Closure Head Studs
  - RT of SG safeend to piping welds
3.2 Qualification Application in China

Stage 2 in 2010

- **Conventional Qualification (Lingao 3/4 NPP)**
  - Manual UT of SG Tube sheet-to-channel head welds
  - Manual UT of PRZ manhole studs

- **No requiring Qualification (Lingao 3/4 NPP)**
  - PT of Nuclear Class 1 component
  - VT of Nuclear Class 1 component
  - RT of welds of Nuclear Class1 component (Universal)
  - UT of piping welds of ARE/ASG/VVO system
3.2 Qualification Application in China

Stage 3 from 2011-Present

- NNSA serves as QB
- Integrated Qualification of Fuqing NPP with RSE-M (97) had been completed
  - All NDT Method
  - All inspection items defined in inspection program
3.2 Qualification Application in China

Stage 3 from 2011-Present

- **Specific Qualification (Fuqing NPP)**
  - ET of SG tubes
  - RT of RPV Safeend welds
  - UT of RPV Safeend dissimilar metal welds
  - UT of RPV Safeend to piping welds (equivalent to the result qualified in UK-IVC)
  - UT of RPV Shell welds) (equivalent to the result qualified in UK-IVC
  - UT of RPV internal Cladding (equivalent to the result qualified in UK-IVC)
  - UT of RPV Nozzle welds (equivalent to the result qualified in UK-IVC)
3.2 Qualification Application in China

Stage 3 from 2011-Present

- **General Qualification (Fuqing NPP) 17**
  - CCTV of RPV internal cladding
  - RT of RPV Nozzle safeend to piping welds
  - ET of RPV Closure Head Studs/Nuts
- **Conventional Qualification (Fuqing NPP) 13**
  - UT of Flange and Ligament between internal threads
  - Manual UT of SG Tube sheet-to-channel head welds
  - Manual UT of PRZ manhole studs
  - RT of Upper head to shell welds
- **No requiring Qualification (Fuqing NPP) 16**
3.2 Qualification Application in China

Stage 3 from 2011-Present

- A set of general Procedures are set up on base of qualified procedure, equipment and personnel
- The new qualification of NPP units with similar design will not be done with ENIQ, instead of reviewing the documents compared with qualified technique
3.3 Inspection qualification for qinshan III (CANDU)

According to the requirement of the laws and regulations, ISI/PSI technology must be qualified in all units of NPPs in China. QS No.3 NPP (CANDU) qualification preparations are under way.
Thank you!