New reactor Internal Pumps in Olkiluoto 1 and 2

Mats Olsson Westinghouse Sweden
Sebastian Trappen KSB
Introduction/background

Replacement of Reactor Internal Pumps in Olkiluoto 1 and 2

- Introduction/background
- Project set-up, scope, schedule
- Technical solutions
- Challenges/risks
- Lessons learned
Introduction/background

TVO need to replace existing reactor internal pumps in Olkiluoto 1 and 2 because of

- design life reached for the existing system and difficult to get spare parts

In addition, the technical solution should
- be prepared for a future power uprate (+20% flow rate)
- enable the drive system to be classified non-safety
Technical solutions

Reactor internal pumps has less inertia compared with external pumps, and to maintain dryout margins, additional inertia are installed in the drive systems

- **Oskarshamn 1 Ringhals 1**
  1\textsuperscript{st} generation Atom BWR, external pumps

- **Forsmark 1,2 (Olkiluoto 1,2)**
  3\textsuperscript{rd} generation Atom BWR, internal pumps

- **Oskarshamn 3**
  4\textsuperscript{th} generation Atom BWR, internal pumps
Technical Solution

KSB PSR 570-FW pump

Wet-winding motor pump unit with internal flywheel

New pump utilizing existing diffusor
No changes of RPV connections

Increased
- pump length + 400 mm
- weight + 1670 kg
New Reactor Internal Pump design data

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>Uprate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Points OP 1</td>
<td>OP 1</td>
<td>OP 1</td>
</tr>
<tr>
<td>Operating Points OP 2</td>
<td>OP 2</td>
<td>OP 2</td>
</tr>
<tr>
<td>Q [m³/s] per pump</td>
<td>1,65</td>
<td>1,96</td>
</tr>
<tr>
<td>H [m]</td>
<td>23</td>
<td>33</td>
</tr>
<tr>
<td>n [rpm]</td>
<td>max = 1550</td>
<td>41</td>
</tr>
</tbody>
</table>

Operating Temperature [°C] 274
Operating Pressure [kPa] 7400
Design Temperature [°C] 300
Design Pressure [kPa] 8500
Project set-up, scope and schedule
Division of Responsibility (DOR) - Communication

Close communication between all parties facilitated by integrating KSB into the project team.
Scope overview

- Design/engineering, manufacturing, licensing and delivery of 12 + 4 reactor internal pumps
- Testing including
  - Hydraulic model test
  - Full load motor test (48 h on each motor)
  - Coast down test
- Service equipment
  - New hovercraft
  - Design and delivery of ~20 new tools and adaptation of a few existing tools
  - Diffusor wearing tool
- Piping
  - Strength calculations
  - Pipe connections
- Installation
- Commissioning
- Training
Partial Deliveries

- Three partial deliveries for installation at the outage each year

<table>
<thead>
<tr>
<th>No</th>
<th>Description</th>
<th>Delivery year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>One (1) RIP installed for OL1</td>
<td>2016</td>
</tr>
<tr>
<td>2</td>
<td>Six (6) RIPS installed + two (2) spare RIPS for OL2</td>
<td>2017</td>
</tr>
<tr>
<td>3</td>
<td>Five (5) RIPS installed + two (2) spare RIPS for OL1</td>
<td>2018</td>
</tr>
</tbody>
</table>
Schedule overview

**Contract**
- Overall Project documentation
- Manufacturing approval
- Hydraulic model test
- Manufacturing start of special tools

**FAT of 1st pump**
- FAT of special tools
- Delivery to Olkiluoto of 1st RIP

**Completed installation of 1st RIP**
- FAT and delivery of RIPS for OL2
- Installation OL2
- Delivery of RIPS for OL1

**Installation OL1**

**July 2014**
- July 2014
- Oct 2014
- Dec 2014
- Feb 2015
- Mar 2015

**Feb 2016**
- Feb 2016
- April 2016
- May 2016

**June 2016**
- June 2016
- Feb 2017
- June 2017
- Feb 2018

**June 2018**
- June 2018
Challenges
Challenges

• Short lead time, less than 2 years(!) from contract signing until finalized installation of the first pump
• New YVL guides applied for the first time in a project of this size

• Interface towards a new drive system
• New pump utilizing existing diffusor
• Diffuser wear ring issue (old rings stuck)
Challenges

• Several projects in the reactor pressure vessel on-going at the same time with risk of interferences

• Installation, testing and commissioning of pumps within available outage window

• Limited space for installation
  - Downcumer
  - Pumpdeck
  - Transport path
Limited space for installation

Pump impeller/shaft need to be transported horizontal in the downcumer. Then sliding on the core shroud and the pump diffusor.
Tools overview

- Special tools for mounting and dismounting the pumps are included in the scope of supply
- The tools are divided into three groups
  - The new hovercraft
  - Adoption of the design of existing tools
  - Redesign of existing tool for replacement of diffuser wear ring for the test in 2015
Limited space for pump handling
Factory testing and verifications
Functional Testings and Verifications

KSB workshop in Frankenthal

February 2015
• Hydraulic model test

Autumn 2015 (first assembly)
• Functional testing in the test loop
• Verification of special tools together with the first pump

February 2016
• Factory Acceptance Test (FAT)
• Full load motor test (48 hours)

June 2016
• Site test/verifications first RIP

November 2016
• Coast Down Test (all pumps in test loop)
Functional Testing (hydraulic model test)

Approval of testing organization according to YVL 1.3

Hydraulic Model Test

- acc. ISO 9906
- Modeling based on affinity laws
- Comparison of both impeller versions
Factory Acceptance Test incl. 48 hours test

- Original drive system used
- 10 starts and stops
- 48 h endurance test
- Different load points
Coast Down Curve measured vs. calculated

Coast Down Time

- Measured in OL 1 (blue)
- Cold reactor, all six RIPs tripped together
- Test results are showing excellent correspondence with calculated curve
Coast Down Test (November 2016)

- To verify coast down time of the RIP
- New test loop developed and installed
- Complete loop optimized via. CFD (similar flow conditions as in the RPV)
Outage Planning and Pump Installation 2016
Installation of Reactor Internal Pumps

The installation of the new RIP were very similar to an ordinary maintenance outage when pumps are replaced for maintenance.

The main differences were:

• The number of pumps to be changed
• Two sets of special tools are needed
• Rerouting and welding of cooling and drainage pipes
• Installation of new power cables
• Installation of new diffusor wear rings
Installation of Reactor Internal Pump 2016

Overview of site sequence

<table>
<thead>
<tr>
<th>DOR</th>
<th>WSE</th>
<th>TVO (FECO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>S</td>
<td>R</td>
</tr>
<tr>
<td>R</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>S</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>S</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>-</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>S</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>-</td>
<td>R</td>
<td>R</td>
</tr>
</tbody>
</table>

S= Support
R=Responsible

12 days

Insulation measurement
Phase rotational check
Rotation check

Commissioning certificate
PTR
PTO certificate

30 days

Grid

open reactor
closed reactor
In general installation went very well

- Pump installed according to plan incl diffusor wear ring
  - CI* pump April 21
  - Delivery to site (pump and tools) May 6
  - Approved receipt inspection May 10
  - Disassembly of pump for inspection (pump/tools) May 17
  - CI piping material May 21
  - CI cooling piping installation May 26
  - CI small bore piping installation May 28
  - Construction inspection complete installation June 1

- Very good co-operation Westinghouse/KSB/TVO/STUK on site
  * CI=Construction Inspection
Lessons learned / Risk process
Iterative Risk process

Risks identified and handled at regularly
- Weekly meetings (WSE/KSB)
- Monthly Project meetings WSE/TVO/KSB
- Regular joint STECO-meetings

Example of major mitigated risks:
- Short schedule
- New design – short delivery time
- Handling tools – new pump, new tools design
- Installation schedule
- Diffuser wear ring issue (old rings stuck)
Lessons Learned / Summary
Lessons Learned / Summary

- Short lead time – full time committed project team
- Mixed project team - less interfaces
- Successful iterative risk process (TVO/W/KSB)
- Licensing documentation - early involvement of STUK
- The pre-installation of one pump gave many very valuable experiences for the coming installations.
- Engineering team (W/KSB) on site resulted in that questions/issues could quickly be resolved

- Next year – Target to keep as many from installation team as possible. Less engineering support but Lead Engineer and Piping supervisor will still be needed on site.
Thank you!