ABSTRACT
Based on our extensive inspection experience and existing tool set for non-destructive examination (NDE) of GEN-2 Power Plants, AREVA NDE solutions has developed solutions for the GEN-3 EPR reactor main coolant line (MCL) component NDE. The tools and techniques developed and discussed in this paper are:

- ISIM and TWS manipulators for the Reactor Vessel using RT, UT and VT techniques
- The RANGER manipulator associated with advanced ET generator and pusher-puller for Steam Generator tubes
  - ET and PT techniques for Vessel Bolting
  - VT techniques for Vessel Head Cladding and Cover Head

The EPR reactor is designed to increase safety, in-service availability and operational performance. This has led to new main coolant circuits components requiring new features and adaptation of existing tools. Most of these changes only mandated re-work of technical justification, personal training and qualification files. For vessel head cladding visual tests however, a new manipulator has been qualified.

In addition, two new examinations have been required including:

- Examination of 44 welds of the Main Circuit Line located on the hot leg, cold leg and U-shaped leg using Phase Array UT techniques
- Examination of the newly designed Control Rod Drive Mechanism Housing (CRDM-H) using UT or ET techniques

INTRODUCTION
Associated to the development of GEN 3 Power Plants AREVA NDE-Solutions is capable of offering a full set of inspections techniques for PSI and ISI of the EPR™ reactor main primary components. Moreover, examination techniques have been developed and qualified for various customers and standards. These examination capacities are described for each of the primary component hereafter.

REACTOR PRESSURE VESSEL INSPECTION
For reactor pressure vessel inspection, two manipulators have been qualified in deference to different codes, standards, and examination techniques required by and the customers:

- ISIM : In Service Inspection Machine (ET/VT/UT/RT inspection techniques),
- TWS : Trans World Service (ET/UT/VT inspection techniques).
Both manipulators use the same UT equipment: SAPHIR+ developed by AREVA NDE Solutions Germany

All examination techniques have been developed using advanced technology including simulation tools and qualification tests on various representative mock-ups
Figure 3: Overview of examination techniques

Figure 4: Synthesis of examined areas and applied examination techniques
STEAM GENERATOR TUBE NDE FOR EPR™

For EPR™ Steam generator tube inspection, a single manipulator, RANGER, is used associated with the MIZ 80/81 advanced pusher-puller by AREVA NDE Solutions worldwide. This set of equipment allows deploying either single bobbin coils, rotating probes or phased array probes. Moreover, the RANGER manipulator is also qualified for light maintenance operations such as tube plugging.

Figure 5: Ranger manipulator fitted for dual bobbin examination

Figure 6: Dual pusher puller on steam generator platform
**EPR™ BOLTING STUDS AND NUTS INSPECTION**

For **EPR™** bolting a new generation of inspection machine has been developed though the examination techniques remain identical to traditional Gen 2 approaches (ET and PT for studs threads).

![Figure 7: Stud inspection machine](image)

**Figure 7: Stud inspection machine**

![Figure 8: Nut inspection machine](image)

**Figure 8: Nut inspection machine**
**EPR™ VESSEL HEAD CLADDING INSPECTION**

For **EPR™** Vessel head cladding a new generation video endoscope inspection machine has been developed including the ability to characterize potential eventual degradations. This new capacity has been extended to previous inspection systems with full customer satisfaction.

![Design of the vessel cladding inspection machine](image)

**Figure 9:** Design of the vessel cladding inspection machine

![Example qualification pictures](image)

Cone + thermal sleeve  Cone  Cone detail

**Figure 10:** Example qualification pictures
INSPECTION OF EPR’S™ 44 MAIN COOLANT LINE WELDS
The EPR™ Main coolant line has been designed to allow UT inspection of the complete set of forty four (44) welds. So it was necessary to develop and qualify new inspection techniques. Among the 44 welds to be inspected, it possible to identify three different cases corresponding with three different inspection techniques:

- Homogenous welds
- Dissimilar weld (piping to vessel and piping to SG)
- Homogenous weld piping to pumps (forged-pipe to cast austenitic steel pump casing)

The manipulator is an extension of AREVA NDE Solution’s PRIMUS pipe inspection system and is positioned on the pipe to be inspected thanks to removable tracks installed on two fixed supports.

The inspection technique uses phased array UT probes with adapted focal laws.

Figure 11: PRIMUS manipulator with probes installed on piping

Figure 12: Welds to be inspected
**EPR™ CONTROL ROD DRIVE MECHANISM HOUSING INSPECTION**

The **EPR™** vessel head is fitted with newly designed Control Rod Drive Mechanism Housings. New inspections techniques have been developed for the four (4) welds to be inspected.

**Inspection technique:**
ET rotating probe from inner surface with manipulator under vessel head.

**Inspection technique:**
UT from outer surface and top of vessel head.

Figure 13: Welds to be inspected

Welds 2/3, 3/4 and 4/5 are inspected from inner surface by ET technique with a rotating probe and a MIZ 81 pusher-puller coupled with the manipulator shown on figure 15 allowing insertion of the probe into the CRDM housing.

Weld 1/2 is inspected from the outer surface by UT techniques thanks to the manipulator shown on figure 14 and using SAPHIR + UT instrument.

Moreover, both inspections can be performed simultaneously by two different inspection teams.
Figure 14: UT Manipulator fitted with UT probes and coupling retrieval system

Figure 15: ET Manipulator fitted with MIZ81 ET Instrument