Abstract of presentation:

Modernization of Kozloduy Nuclear Power Plant units 5&6 -
Implementation of new monitoring and diagnostic systems for the reactor primary circuit

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Summary:

To improve the reliability of Kozloduy Nuclear power plant several modernization measures will be implemented during the outages in the years 2003 to 2005. In the area of the reactor primary circuit the following diagnostic systems will be installed during outage 2003 in unit 6:

- Loose Part Monitoring System – KÜS’95
- Moisture Leakage Monitoring System – FLÜS
- Fatigue Monitoring System - FAMOS

The new monitoring systems will be shortly presented. The project organization as well as the sequence and schedule of the implementation during the short outage time window will be shown. The benefit in terms of reliability gain for the operation of the power plant will be explained.
Background

In 1995 the IAEA issued findings and recommendations for VVER 1000:
- I&C6: "... Diagnostic systems are needed to provide the operators with an early warning of mechanical equipment degradation, in order to avoid termination of safe operation as a consequence of a sudden failure."
- I&C7: There is a "... lack of monitoring and assessing the unspecified loads. In penetrations, nozzles and in certain piping, high thermal loads relevant for fatigue analysis have been expected and in many cases treated with specific design... It is common practice according to reference codes and standards to implement monitoring system to ensure the required integrity is maintained for components concerned."

On base on the IAEA recommendation there were included the following three measures in the Modernization Program for NPP Kozloduy 5&6:

- Measure 12332 - Implement a system for detection of loose parts (KÜS’95)
- Measure 12333 - Implement a system for quick detection and localization of leakage from primary circuit (FLÜS)
- Measure 12362 - Implement a system for monitoring of thermal cycles on coolant system piping (FAMOS)

Objective

The KÜS, FLÜS and FAMOS are part of the Framatome ANP Diagnostic Systems.

a) Loose part monitoring system - KÜS’95

The main aim of the KÜS’95 is to detect loose parts in the primary circuit, to determine the location of the loose parts as well as the approximate weight of the part and to decide, if the plant can be continued to operate.

The main features are
- Continuous, uninterrupted monitoring
- Minimization of spurious alarms
- Automatic detection and localization of the event
- Interactive mass estimation
- Fully automatic operation including:
  - Status logs
  - Event documentation
  - System self-test

In case of detection of loose parts an alarm will be generated and announced in the Main control room. The analysis of the data can be done online on the evaluation cabinet or with the offline software on a separate PC, which can be connected to the offline partition of the evaluation (online) PC via LAN. For a better evaluation a set of plant operational data will be transmitted from the Computer Information System (CIS) to the KÜS’95 system.
For KNPP 5&6 the KÜS sensors will be installed on:
- Main Coolant pump
- SG primary side (hot leg)
- SG secondary side (feed water line)
- PRV outlet nozzles
- RPV bottom

b) Leak detection monitoring system - FLÜS

The main aim of the FLÜS is to detect leakage in primary circuit, to determine the location of the leakage, to make assessment for trending of leaking and to make leak rate assessment.

The main features are
- Continuous, uninterrupted monitoring
- Automatic detection and localization of the event
- High sensitivity for local monitoring of $\leq 1$ kg/h
- Combination of local monitoring with efficiency of global monitoring

In case of detection of leakage an alarm will be generated and announced in the Main control room. The analysis of the data can be done online on the evaluation cabinet or with the offline software on a separate PC, which can be connected to the offline partition of the evaluation (online) PC via LAN.

For KNPP 5&6 the FLÜS lines will be installed as follows:
- Measuring line 1: Primary loops 1+4
- Measuring line 2: Primary loops 2+3
- Measuring line 3: Pressurizer and Surge line
- Measuring line 4: RPV upper block
- Measuring line 5: Global containment monitoring

c) Fatigue monitoring system - FAMOS

The main aim of the FAMOS is to know the fatigue status of the highest loaded components, to find operating modes, which are unfavorable according to fatigue, to establish a basis for fatigue analysis on real operating loads and to use the results for life-time management and life-time extension.

In general the FAMOS contains of 4 stages:
- Stage 0: Fatigue manual
Where, why and how the instrumentation has to be applied under consideration of Operating procedures which cause thermal shock or stratification, Existing stress or fatigue analyses, Operating experience of the staff and experience of FANP
- Stage 1: Data Acquisition
Data collection on Magneto Optical Disc (MOD) during plant operation
- Stage 2: Quick evaluation Load level \((T,p)\)
Graphic display of load and system data; Quick look evaluation, a plausibility check is performed first, fault detection and correction routines are used to generate a clean database, Quick evaluation of fatigue-related parameters is performed automatically for all components and a “Rainflow” algorithm is used to analyze the temperature and pressure fluctuations

- Stage 3: Fatigue Analysis, Strain Level \((s,e)\) – this is not part of Framatome ANP delivery for KNPP5&6
Stage 3 is necessary only if Stage 2 has identified significant loads, the measured pressure and temperature profiles at predefined locations are converted into stress profiles with the inside wall temperature, a “Rainflow” algorithm is used to evaluate the time histories of the stress intensities, Superposition of loads consider:
  - slug flow
  - thermal stratification
  - internal pressure and
  - any section forces and moments
The result of the calculation is the partial usage factor \(\Delta U\) in the period of observation \(\Delta t\).

For a better evaluation a set of plant operational data will be transmitted from the Computer Information System (CIS) to the FAMOS system.

For KNPP 5&6 the FAMOS sensors will be installed on:
- Primary Coolant Purification System - TC10 (30)
- Pressurizer Cold spray line - YP10
- Pressurizer discharge line - YP20 (Unit 5)
- Hydroaccumulator lines - YT11,12 (Unit 5)
- Low pressure safety injection system - TQ12 (32)
- Primary Circuit Cooldown line - TQ40 (Unit 6)
- Emergency feed water line - TX10
- Main feed water line - TX41
- Steam Generator Cold collector YB10W01

d) Main Interfaces

The following main interfaces to the plant had to be considered:
- Coordination of sensor positions of KÜS, FLÜS and FAMOS
- Replacement of Primary Circuit insulation (measure 11321)
- Connection to Containment penetrations (KNPP measure for replacement)
- Integration in plant buildings
- Connection to existing plant I&C and alarm system
- Connection to plant power supply systems

The project organization had to assure efficient work between the employer KNPP, the main contractor for the diagnostic systems Framatome ANP GmbH, the Bulgarian companies ENPRO Consult for the detail design and Enemona for the site works.

As a result of the design works documents were elaborated, showing the sensors of all three measures in the same drawings. The evaluation cabinets for KÜS, FLÜS and FAMOS will be
installed in the same room (CIS) in one row, thus there will be one common base frame (together with the cabinet for the H2 monitoring system)

Not only the design activities, but also the installation activities have to be coordinated, e.g. with the activities of Framatome ANP S.A. (Replacement of primary circuit insulation) and the KNPP in-service inspections and maintenance. Thus, to manage the installation, testing and commissioning activities within the allowable period of appr. 50 days during the outage is a real challenge.

**Conclusions**

The Framatome ANP GmbH diagnostic systems KÜS’95, FLÜS and FAMOS will help to
- Detect damages early
- Prevent consequential damages and unnecessary shut-downs
- Initiate suitable corrective measures in time
- Fatigue monitoring provides the necessary data for the evaluation of the fatigue behavior on the basis of real operating loads
- The results can also serve as a base for life time extension

Thus, the implementation of the new diagnostic systems in KNPP Unit 5&6 will increase reliable operation of the Kozloduy nuclear power plant.