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MODERNIZATION OF THE NUCLEAR POWER PLANT KRŠKO WITH NEW STEAM GENERATORS

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1 INTRODUCTION

The contract for the replacement of two steam generators at NPP Krško was awarded in February 1998 to the Consortium SIEMENS AG   FRAMATOME S.A.. The time frame for the replacement outage was scheduled from April to June 2000. The replacement itself started with the plant shut down on 15th of April 2000 and the plant was back on line on 15th of June, so that after an intensive engineering period of more than two years the plant was off line only 62 days, as scheduled.

This document deals with the various aspects of the replacement phase itself and the techniques used. During the last years conference the engineering and licensing phase of the project have been presented.

2 RIGGING EQUIPMENT

2.1 Outside Lifting Tower

For the lifting/lowering of the SG`s from the reactor operating deck on El.115m to the ground level on El.100m and opposite, an outside lifting tower was installed. The system enabled vertical hoisting and horizontal shifting of loads. The SG lowering/lifting was performed by 4 x 200t wire jacks. The lifting tower consisted of: two towers, two heavy load girders with a length of 34m each, two cross beams incl. 2 x 200t wire jacks for horizontal movement and 4 x 200t wire jacks for vertical movements.

Additionally an auxiliary 10t trolley was attached to the heavy load girders to allow lifting of materials, tools, containers etc. into and out of RB.

During the engineering phase it was determined, that the safety related systems namely the Refueling Water Storage Tank and the Reactor Make Up Water Tank – which were in the vicinity of the lifting tower- may be affected by the installation of the lifting system before cold shut down conditions (plant mode 5) are reached. Due to this reason the lifting tower could only be installed to the half of its height before shut down and completed after the required mode was reached, namely after the equipment hatch was closed again for core off load, because during installation of the system it was not possible to perform any transports into RB.

A load test of the system on site was not necessary, because it was demonstrated in the factory that the main girders could withstand the load. The design load of the girders is 420t and these girders were also used during other replacements and for heavy load performances.

After a functional test, the lifting system was released by the authority on 27th of April 2000. During the SG manipulation the system always functioned reliable.

2.2 Sliding System and Cavity Cover

In order to allow the horizontal movement of the SG`s in and out of RB, a sliding system was installed containing two parts – an outer part and an inner part (2 beams each part with bracing). The borderline of the two parts was inside the equipment hatch.

The outer part was installed as soon as the equipment hatch was closed and after all transports into RB have been performed. The inner part was erected as soon as the equipment hatch was re-opened after defueling and the missile shields were placed back on their operating position above the RPV, because the intermediate storage area of the missile shields interfered with the sliding beams.

The heavy runway was equipped with two supports on top in order to carry the SG`s out/in. One support (sliding saddle) was attached to the steam dome, the other one (tilting device) was mounted on the channel head to allow the tilting from the horizontal to the upright position.

Due to transport- and scheduling reasons a light transport system with a winch driven trolley was installed prior to place the heavy runway, to allow different transports –such as scaffolding, shielding and insulation- in and out of the RB.

Additionally, a small transport system was installed through the emergency hatch to facilitate the transport of tools, lead blankets etc. to the loop areas. The emergency hatch is located at El.100m. These measures shortened the transportation time.

As soon as the missile shields were placed back in their operating position above the RPV, a specially designed cover was installed above the reactor cavity in order to prevent foreign parts from entering the cavity during the execution of the replacement. The missile shields were integrated in this cover. The cavity cover was removed, when all work above the reactor operating deck had been completed. The load capacity of the Cover was 1t/m², providing also additional storage areas for materials and equipment.

2.3 Polar Crane Gantry

The polar crane in the existing configuration didn`t allow the lifting of the SG`s in terms of lifting height and trolley capacity.

The installation of an auxiliary lifting gantry on top of the polar crane girders achieved the required properties. The gantry substituted the existing trolley, which was parked at one end of the polar crane bridge, during lifting operations.

The gantry consisted of an auxiliary trolley with an axial bearing- to allow rotation- and a 400t wire jack for lifting purposes.

The wire jack was equipped with a spreader beam, which was attached to the SG`s. In order to avoid a complicated load test, calculations according to ANSI 30.b proved the reliability of the equipment and the crane.

The authority released the lifting gantry and the polar crane on 4th of May 2000. During lifting operation optical measurements were taken to determine the deflection of the polar crane girders. The deflection of the polar crane bridge was always within the allowed limits.

Note: the weight of the old SG was 320t each and the weight of the new ones was 343t each. The weight of the gantry itself was ~30t.

The SG lifting operations started on 5th of May and were finished on 14th of May 2000.

2.4 Auxiliary Cranes

In order to have sufficient lifting equipment inside RB and to be independent from the existing polar crane, three auxiliary cranes were installed- one on the top of each cubicle with a lifting capacity of 1t each and one on the RPV Head intermediate storage area with a capacity of 1.5t

This area was chosen to take materials, tools etc. from the equipment hatch and lower them through the material opening to the lower elevations. This was the only possibility to transport things to the lower elevations while the SG`s were in place. Each auxiliary crane consisted of a support column and a crane arm equipped with an electrical driven trolley.

3 RCS – ACTIVITIES

3.1 Optical measurement

Due to the chosen two-cut method on the RCS (one cut on each primary nozzle) and the narrow fit up tolerances of the pipe ends to the nozzles required by the narrow gap welding process, the following optical measurement steps were performed:

- ☑ Measurement of existing system during pre-outage
- ☑ Measurement of new SG`s in ENSA work shop prior to shipment (Comparison of the results from step 1 and 2 in order to confirm the two-cut method)
- ☑ Measurement of the new SG`s on site in order to determine the bevel location on the nozzles
- ☑ Measurement of new SG`s after beveling (Comparison of the results of step 1 and 4 in order to define the cut lines on the existing system)
- ☑ Confirmation of the cut lines on the existing system
- ☑ Measurement of the RCS pipe ends after cutting (in blocked position) and after SG removal
- ☑ Measurements during pipe displacement

- ☑ Measurement of RCS pipe ends in fit up position prior to machining (Comparison of data to define the new bevel location)
- ☑ Alignment of reference ring on the new bevel location by optical measurement
- ☑ AS BUILT measurement after welding and NDE of RCS

The basic technique for the optical measurement is the determination of 3D-coordinates of object point by optical focusing and triangular calculations. Therefore an industrial measurement system with electronic theodolites was chosen for the replacement.

The measurement system consisted of electronically combined theodolites and a PC for data processing equipped with special software. One to 4 theodolites were used together within one survey cycle. Simultaneously with the measurements, verification calculations were performed in order to detect questionable results. The data evaluation was performed outside RB.

The use of optical measurement showed excellent results in Krško, as well as in previously performed projects

3.2 Reactor Coolant System (RCS) - Clamping and Fit up

Prior to cutting RCS, each Hot Leg and Crossover Leg was blocked in its original position by using a clamping device equipped with hydro jacks. Each hydraulic unit was equipped with fine scale manometers to monitor the pressure respectively the displacements. The hydro jacks were not only used for blocking the system; they were also used for the pipe displacements which were necessary to minimize pipe stress which would have been otherwise induced by the occurring weld shrinkage. and the fit-up of each pipe end to the relevant nozzle. The device was designed in such a way to cover all moving directions (x-y-z axis)

The allowable displacement respectively the forces were verified by several intensive calculations.

Due to the conditions inside the cubicles and the heavy design of the device itself, the installation of the clamping device was a time- and radiation dose intensive job. Due to other maintenance work of NEK at the RCS-Lines, the pipes could not be filled in order to reduce the dose level. Shielding also had to be removed on the locations were the device was installed on the piping.

Nevertheless both SG`s were fitted, fulfilling all technical requirements of the narrow gap welding technique and pipe stress analysis.

3.3 RCS- Cutting and Machining

A mechanical process was used for RCS-cutting and machining due to the ALARA principle. The cutting machines were mounted and aligned on the RCS pipes. The machines were driven by hydraulic power units. Both cuts- HL and XOL- were performed simultaneously and in two steps.

Step 1: Cutting with a blade cutter up to ~95% of the wall cut. The re-indexing of the blade cutters depth was achieved automatically at each rotation.

Step 2 : Replacement of the blade cutters by cutting wheels and cut completion. The cutting wheel has the advantage, that no debris is produced, which can enter the primary system. So the primary man ways don´t have to be opened to set a plug for foreign material exclusion.

Start of RCS – Cutting on the 4th of May was also the start of the S/F contractual replacement window requiring 28 days.

The machining of the remaining pipe ends was performed after decontamination and optical measurement. The beveling machines were centered in the pipes and adjusted with a reference ring, which was aligned by optical measurement.

The machines were equipped with spherical ball joints and with mechanical jacks to allow fine adjustment. Both joints on each loop were machined in parallel and with great accuracy. The weld edge geometry was given by the GTAW narrow gap welding process.

3.4 RCS – Pipe End Decontamination

After removal of the old SG`s, the pipe end decontamination took place in order to lower the dose level for the next following activities like optical measurement, machining, welding etc.

The measurements on the open pipe ends showed a contact radiation dose level inside the pipes between 60 – 130 mSv.

For the decontamination, a mechanically abrasive (sandblasting) process was selected. This process produces less waste than a chemical process. The results between both methods can be compared.

Prior to starting the process a leak tight seal disc was inserted into the pipes to avoid blasting media from entering the reactor coolant system. Then the equipment was mounted on the pipe end, consisting of : front box with a clamping device and the manipulator with rotating nozzles.

A compressor was placed outside the RB to supply sufficient air capacity with the required pressure of 8 bars.

The performance was done in two steps:

*Step 1***:** Blasting with an electro-corundum to remove the oxide layer with high radiation

Step 2: Blasting with glass beads to improve the superficial stress conditions and to smoothen the surface

A closed-circuit system with underpressure was used to avoid aerosols. The decon depth was ~ 500mm. After decontamination, a shielding plug was inserted into each pipe end to separate the decontaminated area from the non-decontaminated area.

A dose reduction factor between 40 – 60 was achieved.

3.5 RCS – Welding

The welding of the remaining pipe ends to the SG- nozzles was performed with a remote controlled mechanized GTAW process with a special narrow gap weld geometry.

A layer by layer technique was used with constant welding parameters around the circumference.

The welding stations were placed on the El.100m in a low radiation dose area.

Hot Leg and Crossover Leg were welded simultaneously. By the time the last SG was fitted up 4 welding machines were operating in parallel. Due to the high welding energy, welding was performed in 2x 10h shifts, 4 hours were needed to cool down the pipes.

After app. 25 layers an intermediate X-Ray was performed with the root already ground. After welding completion and weld built up, the joints were ground mechanically with a special geometry for ultra sonic testing (ISI). The grinding was followed by the required NDE (X-ray).

No repairable indication was detected on any of the four joints.

3.6 RCS – Video Inspection and Closing of Man Ways

After all RCS piping was performed, the shielding plugs were removed through the manways via the channel head; this was followed by FOSAR (Foreign Object Search and Retrieval) of the primary side to ensure that no foreign material , which could cause damage to the components or fuel elements, was left in the circuit.

The inspection was recorded on a VHS videotape.

After the cleanliness was ensured, the primary man ways were released for closing.

For handling of the primary manway covers a special handling device (swivel arm) was designed and installed. For tensioning the studs of the covers a multi stud tensioner was used.

On 31st of May, 27days after the first cut, the primary side was closed and ready for filling.

4 SECONDARY- AND AUXILIARY PIPING

4.1 Main Steam Line

Only for clearance purposes for SG-Rigging, a section of the main steam line was removed. The MS-Restraint was also removed due to the fact that the auxiliary cranes were installed in that location. As soon as the new SG was back in place the existing pipe spool was machined and re-welded followed by NDE. When the relevant aux. crane was dismantled, the restraint was reinstalled.

4.2 Main Feedwater Line

The old SG`s were equipped with a preheater. The FW- nozzle was located closely above the tube plate. The new SG`s do not have preheaters and the feedwater nozzle is located in the conical part of the SG., that means approximately 8 m higher than the existing one.

Due to this fact the feedwater line was rerouted inside the cubicles to connect it to the new nozzle location. Therefore also new supports and restraints were installed. Due to new floor response spectra a lot of supports inside RB as well as in the intermediate building were also modified.

Furthermore the preheater bypass- and warming up line was removed, because the new SG`s do not have preheaters, as already mentioned.

Also the internals of the feedwater control valves were changed to allow higher flow rates due to uprate.

The impellers of the feedwater pumps were replaced by NEKrsko. Higher feedwater flows and resulting increase pressure drop associated with the uprate required increased pump performance.

4.3 Auxiliary Feedwater Line

In order to allow SG-Rigging a portion of the auxiliary feedwater line was cut out. Once the new SG was in place, this cut out portion was replaced by new pipe material with prefabricated pipe spools.

4.4 Blow Down System / Sampling Lines

The blow down system was completely dismantled from the old SG` nozzle, nearly up to the cubicle penetration, and reinstalled with new pipe material to two new connection points on the new SG`s in order to get a flow rate equal to 5% of the nominal feedwater flow.

Also due to the new seismic response spectra, a lot of supports and restraints were modified or newly installed in the reactor building..

Additionally, new vent lines were installed at the high points and a connection from the Blow Down to the Condensation System was created to be able to fill the BD system and avoid water hammer effects when restarting the system.

Due to the fact that the BD system inside cubicle is located close to the channel head and a lot of other work on the primary side was performed during the BD installation, the work was closely coordinated in order to avoid conflicts and to avoid ferritic pollution from entering the primary system.

The sampling lines were replaced by new material and installed to the connection points on the BD- Line and directly on the new SG:

4.5 SG – Instrumentation

Due to the difference of the nozzle locations between old/new SG, the instrumentation lines were completely cut out, up to the wall of the cubicle, and rerouted with new tubing and pipe material. All welds on the instrumentation lines were socket welds. So no X-ray was required on the welds

4.6 Condensation System

In order to allow the operation of the system, the condensation suction pipe size was increased from 24” to 30” to reduce the pressure drop at uprate flows.

4.7 Primary Drain Lines

The new SG`s are equipped with drain nozzles at each primary manway and at each water chamber in order to allow the complete draining of the primary side of the SG.

Therefore new drain lines, with two root valves on each, have been installed. A quick coupling is connected to each drain line in order to connect a metallic hose for draining the remaining water into the floor drain system.

5 RCS- AND SG-SUPPORTS

In order to allow the RCS- pipe displacement and to have sufficient rigging clearance, the shims on the RCS- restraints, pump tie rods and on the SG –supports were removed. For rigging purposes the upper lateral support ring was dismantled in two pieces and parked inside the cubicle. Prior to the removal the related gaps were measured in “ HOT “ and “COLD” conditions to evaluate the current situation and to adequately restore the shims.

After the new SG`s were in place, the upper lateral support rings and the shims were reinstalled according to the previously measured results.

During the plant heat up, the gaps were checked. At 292°C after a stabilization period of 24h, the final measurement and shimming was performed in order to achieve the required gaps given by Westinghouse.

6 INSULATION

The insulation of the old SG`s was completely removed and stored in containers in the MPB. New metal reflective panels replaced this insulation.

In general the removed piping insulation was re-used. Only if the existing one could not be re-used or due to new pipe routing was this insulation replaced by new panels. The heat loss measurements of the new insulation, after the plant reached HOT STAND BY CONDITIONS (292°C) showed good results.

7 I & C ELECTRICAL PART

Because the new design cables were dismantled or new cables were pulled, power cabinets were rearranged, panels dismantled or new panels installed. All this work was performed in the Main Control Room and in the Electrical Building

8 MULTIPURPOSE BUILDING (MPB) / TEMPORARY ACCESS BUILDING

8.1 MPB

Prior to the replacement a new building was erected for the following purposes:

- ☑ interim storage of new SG`s
- ☑ long term storage of old SG`s
- ☑ storage of low rad waste
- ☑ providing a new decontamination facility
- ☑ providing a training area with a full scale mock up (only lower part of SG)

Prior to the performance of RCS-activities , the following delicate jobs were trained on the mock up in order to familiarize the personnel with the plant conditions: cutting, decontamination, welding, closing of man ways etc.. After the replacement performance, equipment and tools used inside the controlled area were transported to the decontamination shop to be checked and decontaminated.

8.2 Temporary Access Building

For the access to the controlled area a temporary access building (container modules) for S/F was erected and connected to the Fuel Handling Building. The existing access was not capable of handling the number of personnel. The building was equipped with lockers, showers, toilets and a radiation monitoring system to check for contamination. Also The HP control point was also located in this building. More than 38000 Entrances and Exits through the Access Building were estimated

9 START UP & TESTING

More than 100 scheduled tests were performed until the plant was on 100% power. These tests included:

- ☑ System Leakage Tests
- ☑ Flow Rate Tests
- ☑ Level Control Calibration and Verification
- ☑ Checking of set points
- ☑ Heat Loss Measurements
- ☑ Valves Operability Tests
- ☑ Checking of Supports and Snubbers
- ☑ etc.

were successfully completed in close cooperation with NEK. Testing was required to get the permission for start up, criticality and power escalation.

10 RADIATION PROTECTION AND SAFETY

Prior to the performance of tasks, several dose calculations were made based on the dose levels measured in previous outages, on the manpower estimated for the activities and on the time scheduled for the activities.

Based on these calculations and due to ALARA the work processes were optimized and the final amount of shielding was determined. 92t of shielding were installed and removed during the outage. In addition to the lead shielding some measures were taken to reduce the radiation level like

- ☑ Flushing of primary circuit with insertion of H2O2
- ☑ Perform as much work as possible while the SG`s are filled
- ☑ Maintain SG-Secondary Side water level as long as possible
- ☑ Refill XOL immediately after decon till shortly under the shielding plug
- ☑ Filling of RCS immediately after closing the last manway

Prior to dose intensive work job briefing was performed with the work groups in order to familiarize them with the radiation conditions.

The final dose was estimated at 1373manmSv. Due to the fact that more work was performed in the radiation areas than previously scheduled and some radiation levels were higher as previously measured, the actual accumulated dose was 1420 manmSv (measured by electronic dosimeters)

The performance of work regarding safety was good. No serious accident with absence from work happened during the whole outage phase.

11 SCHEDULING

Approximately one year prior to plant shut down a common scheduling team (NEK & S/F) was established in order to define the structure, codification etc. of the schedule , to check for interface activities and to built plan schedule.

It was decided to have one common outage schedule, including all activities. In monthly work sessions the progress of the schedule and the related interfaces were discussed. From November 99 till the middle of February 00 the S/F schedulers were permanently on site for finalizing and optimizing the schedule. The freeze date of the schedule was the middle of February 2000. At that time the schedule consisted of more than 7800 activities (~ 6000 NEK & ~ 1800 S/F). These ~1800 S/F activities were introduced in 124 work orders. The structuring of the work orders were defined and mutually agreed upon.

At the end of the outage the schedule included more than 8000 activities with approximately 19000 relationships implemented.

The common team updated the outage schedule twice a day (at 6°° and 18°°). As soon as updating was performed, the updated version was introduced in the Intranet, so that people could see the new situation immediately and react to this situation. In case of major deviations, the relevant people with no access to Intranet were informed immediately.

For S/F a so-called “4 days schedule” was issued once a day, which showed the present day and the next 3 days. This schedule was the basis for the daily meetings. It has to be pointed out that the cooperation and communication within the team worked very well.

12 KEYDATES AND PHASES OF THE OUTAGE

Start Site implementation	*27.03.00*
Plant Shut Down	*15.04.00*

Core off Loading	*23.04. – 25.04.00*
Start Cutting RCS	*04.05.00*
First SG ready to be rigged out	*05.05.00*
Last new SG aligned and released from PC	*14.05.00*
Welding of RCS incl. NDE	*13.05. – 23.05.00*
RCS ready for filling	*31.05.00*
Start Refueling Preparations	*31.05.00*
Operational Delivery (all systems ready for filling)	*01.06.00*
Reloading of Core	*03.06. – 05.06.00*
Start Heat up of RCS	*10.06.00*
Hot Stand By Conditions achieved (292°C)	*12.06.00*
System Leakage Tests	*12.06. – 13-06.00*
First Criticality	*14.06.00*
Plant Connection to the Grid	*15.06.00*
S/F Replacement Window	*04.05. – 01.06.00 (28 d)*
Breaker to Breaker	*15.04. – 15.06.00 (62 d)*

13 CONCLUSIONS

The steam generator replacement in Krško also showed, that the defined goals were achieved. The work was performed with the required quality, within the established time frame and radiation dose estimation and in a safe manner. NEK supported all Consortium undertakings achieving the forecasted targets. The coordination between the client and the Consortium was performed in a good , open and fair manner. More than 150.000 hours were accumulated by the Consortium for the site implementation of the SG-Replacement. The Consortium SIEMENS AG – FRAMATOME S.A also demonstrated its capability, in such a complex project like the SG-Replacement in Krško, to reach the forecasted targets and to perform the work to the client's satisfaction.