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STEAM GENERATOR REPLACEMENT PROJECT IN 2000

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ABSTRACT – NE Krško has awarded the contract for the Steam Generator Replacement Project, which is one of the modernization projects in Krško, to the Consortium of Siemens / Framatome in February 1998. This paper deals with the various aspects of the project: scope, planning, engineering, preparation of modification packages for licensing, management, major techniques used, etc., showing also the status of the activities for the project which are scheduled to be performed in April through June 2000.
The project is being performed on a "turnkey" basis, that means the Consortium is performing all engineering, preparation of the modification packages and site activities; NE Krško is dealing with the licensing of the project.

1. Project Scope

1.1 Steam Generator Rigging

The rigging package comprises all activities which are required for handling and transportation of old and new steam generators (SG) between the outside storage location in the Multi Purpose Building (MPB) and the SG housings in the Reactor Building (RB). The characteristic data of the steam generator are:

- 2 x old SG, weight: 321 tons; length: 20,65 m; max. diameter: 4474 mm to be transported from RB to final storage in MPB.
- 2 x new SG, weight: 343 tons; length: 20,85 m max. diameter: 4474 mm to be transported from temporary storage in MPB into the RB.

1.1.1 Rigging tasks

The SG transport consists of the following main steps (see figure 1):

- Ground transportation between MPB and RB on ground elevation EL 100m
- SG lifting operation between EL 100m and operation floor level EL 115m
- SG horizontal transfer into and out of RB through equipment hatch on operation floor EL 115m
- SG lifting from operation floor EL 115 into the SG housings on EL 108m

1.1.2 Rigging Equipment

The systems employed for these tasks are mainly based on equipment used in heavy lifting, specially adapted for this purpose. The main components are:

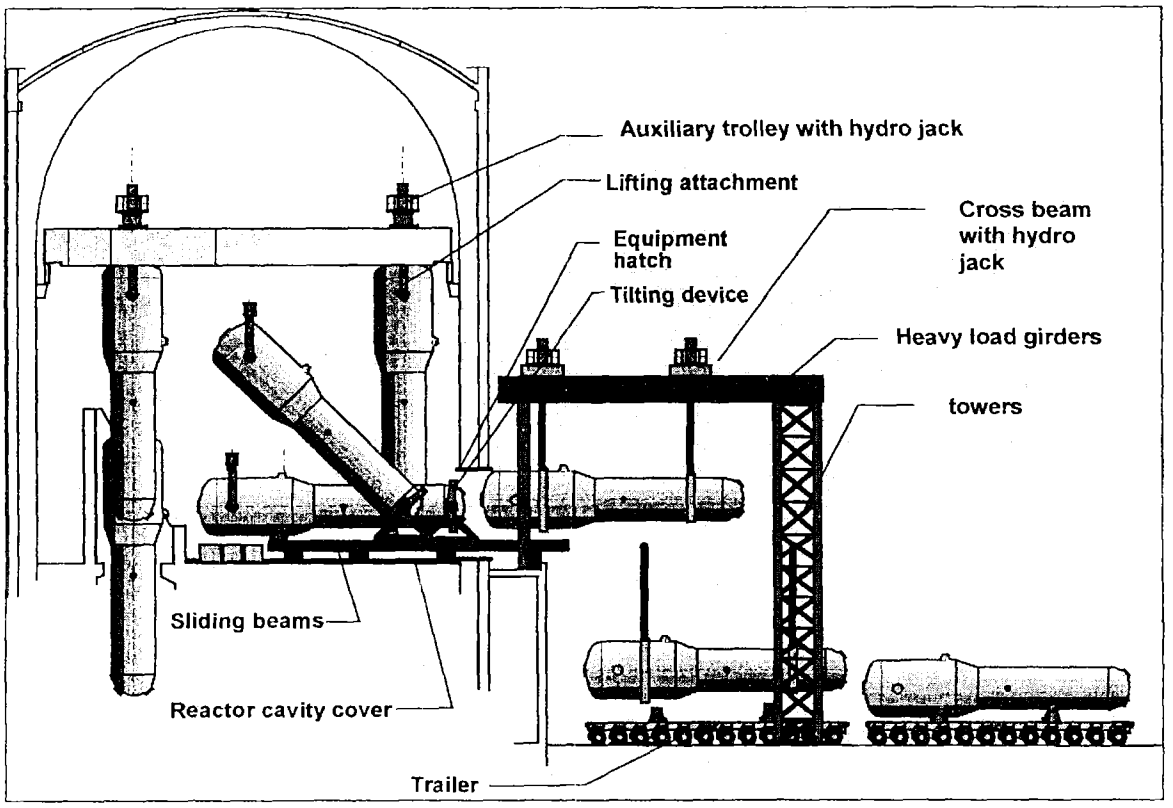

Figure 1: Steam Generator Rigging

Heavy load trailer

The ground transportation is performed by a self-propelled 14 axles heavy load trailer. The chosen trailer is typical for this kind of transport task. The trailer to be used was already employed for previous steam generator replacements (Ringhals 3, Sweden).
The trailer allows transferring loads from storage supports by its integrated hydraulic lifting platform (delta h = +/-300mm). Therefore no additional cranes are required for loading and unloading of the trailer.

Outside Lifting System

For the SG lifting from ground level EL 100 m to operation floor level EL 115m an outside lifting gantry is installed. The lifting system enables vertical hoisting and horizontal shifting of loads. After take over of the steam generator from the transport trailer in horizontal position the SG is lifted by 4 x 200 tons wire jacks. When the steam generator has reached the upper level, it is shifted towards the sliding system on EL 115 m on which the SG is moved into the Reactor Building. The support frame of the lifting system consists of two towers, two heavy load girders (lengths 34 m) and one portal frame in front of the equipment hatch. The towers are built from modular steel elements. The girders and the portal frame are fabricated as standard steel structures.
Two cross beams are installed on top of the girder, each equipped with 2 à 200 tons hydraulic wire jacks. The horizontal sliding of the cross beams is achieved by horizontally installed wire jacks which allow moving both, in parallel or independently from each other.

Sliding System

The equipment hatch in the Reactor Building (RB) has a diameter of 6,95 m. That is sufficient to allow the SG transport into the Reactor Building (RB) through this opening.
The steam generator's horizontal transfer through the equipment hatch is performed by a sliding system resting below the outside lifting system on EL 115 m. The SG is carried by two supports when set onto the sliding system: one at the steam dome side by a sliding saddle and at the channelhead side by the so called tilting device.
The SG is moved into the RB with steam dome ahead. When inside the RB the SG body is brought to a vertical position by means of the polar crane. For this operation the tilting device acts as a bearing to allow for controlled raising of the SG.

Polar crane modifications

The polar crane in the existing configuration does not allow handling the SG as required in terms of lifting height and trolley capacity. The maximal lifting height of the crane trolley is not sufficient to cross the walls of the SG housings with attached steam generator and would require extensive civil works inside the RB.
The polar crane has an original capacity of 320 tons. But the weight of the new Steam Generator is 343 tons. These two deficiencies are remedied by installation of a special auxiliary lifting gantry which provides the required properties. This gantry substitutes the existing trolley which is parked at one end of the bridge. The problem of insufficient lifting height is solved by a suitable design of the hoisting unit and SG attachment plates with optimised length.
The load bearing capacity of the polar crane bridge is improved by the new gantry's lightweight design and an advantageous load distribution. Additional verification calculations for all loaded structures prove this as an acceptable solution. With these measures the polar crane bridge is capable of handling the SG load without structural modifications.
SG lifting is achieved by a 400 ton wire jack. This wire jack is supported by an axial bearing which allows rotating the hanging steam generator about it's vertical axis. This is necessary for the several angular adjustments of the SG during the different rigging phases.

Hydraulic Wire Jacks

Wire jacks are employed within the rigging package in several applications for the handling of heavy loads. Hoisting and horizontal shifting is powered by wire jacks. Wire jacks combine the advantages of hydraulic jacks with the flexibility of cable winches. They provide high hydraulic forces with unlimited lifting stroke. The movements are smooth and they are fail safe under accident conditions due to their working principle.

1.1.3 Specific Requirements

The entire process of SG rigging and handling was investigated in view of nuclear and economical risk. As most of the SGR activities are performed after shutdown of the plant with unloaded core, safety evaluations for nuclear risk deal mainly with the requirement that the fuel in the spent fuel pool is not endangered.
Also conventional risks are to be minimised due to the importance of the power plant for the Slovenian economy. This means that also structures which are not nuclear safety related have to be demonstrated as safe, above normal requirements.

According to a typical SG replacement schedule the outside lifting system is erected prior to the shut down of the plant. According to the results of the safety evaluation this is practically not possible in Krško. It was determined that the safety related systems RWST (Refuelling Water Storage Tank), CST (Condensate Tanks) and Reactor Makeup Water Storage Tank may be affected by the outside lifting system during its installation. As heavy load rigging activities in the vicinity of these tanks would be a potential risk to the nuclear safety of the plant and feasible substitution measures are not available, the early erection of the lifting system is practically ruled out. Therefore the erection activities have to be postponed until after the shut down.

The normally uncritical erection of the outside lifting system may become a critical activity with impact on the overall project time schedule. To minimise negative consequences as much as possible, a very detailed planning of all erection activities is in progress.

1.2 Activities at the reactor coolant pipe

1.2.1 Optical survey, clamping and fit-up

The work package deals with the adaptation of the new steam generators to the existing reactor coolant system (RCS). The SG is separated from the remaining Reactor Coolant System by cuts at the primary nozzles. The fit-up engineering has to provide the basis for the accurate fit-up of the new SG, taking into account the dimensional deviations and the specific requirements of the restoration process. The fit-up activities are performed in close co-operation with the optical survey task. Based on fit-up requirements the optical measurement results are used to determine optimised fit-up positions for the new steam generators. To fulfil these requirements the following tasks have to be considered in this work package:

- accurate dimensional adaptation of new SG and existing RCS
- compensation of weld shrinkage of the new welds
- determination of allowable stresses in the RCS by verification calculations
- dimensional adaptation of SG supports

The fit-up process within a 2-cut steam generator replacement requires the following measurement steps (OM => Optical Measurement):

OM 1	as-built survey of the existing RCS
OM 2	survey of new SGs prior to weld edge preparation
OM 3	survey of new SGs after weld edge preparation
OM 4	survey of RC pipe ends after cutting in blocked position
OM 5	survey of RC pipe ends in fit-up position prior to machining

Applied measurement technique

The basic technique for optical survey is the determination of 3-D coordinates of object points by optical focusing and triangular calculations. For these measurements an industrial measurement system with electronic theodolites is used.
The measuring system consists of electronically combined theodolites and a notebook PC for data processing with specific measuring software. For SG replacement surveys normally 1 to 4 theodolites are used together within one survey. In parallel to the taking of measurements, verification calculations are automatically performed to detect questionable results. These indications are used during the running measurement session, to verify or to correct the received measurement data.

The data evaluation is performed outside of the reactor building. The fit-up calculations are performed with specific software tools which were successfully used in previous steam generator replacements.

1.2.2 Cutting and beveling

The RCS pipe cutting is performed using a mechanical process.

This mechanical cutting allows:

- cutting of stainless steel pipes (external diameter up to 1 m and thickness up to 100 mm)
- outside cut without entering the old SG channelhead
- operation within the limited space around the pipe / nozzle junction

The cutting machine is supported on the RCS pipe. A hydraulic power unit drives the machine. The RCS cutting is performed in two main steps :

- using blade cutters up to 90 % of pipe wall cut. The reindexing of the blade cutter depth is achieved automatically at each rotation
- Before the external cutting tools break through the interior of the pipe, the blade cutters are replaced by cutting wheels which separate the pipe from the old SG without introducing debris into the pipe.

The RCS pipe bevelling is performed after decontamination and optical survey.
The bevelling machine is centred in the pipe and adjusted with the reference ring previously set by optical survey. A spherical ball joint and mechanical jacks installed on the machine allow a fine adjustment of the bevelling machine in concentricity and planeity.
Once adjusted, the bevelling machine is used for machining the new bevel, with a great accuracy, at its exact position on the pipe.
The bevel geometry and its accuracy are in accordance with the welding GTAW Narrow Gap process.
The same equipment will be used to perform the bevel on the new SG nozzles.

1.2.3 Decontamination

The purpose of this process is to reduce radiation dose in the area of reactor coolant pipe ends, and to achieve local cleanliness of pipe interiors. This process is performed in two steps:
Blasting by electrocorundum to remove the oxide layer, followed by blasting with glass beads to improve the superficial stress conditions and to smooth the surface. Use of a closed-circuit system with subatmospheric pressure prevent abrasive particles and dust from escaping into the atmosphere (aerosol build-up is avoided) keeping radioactive waste build-up to a minimum.

1.2.4 Welding

The welds in the RCS piping system will be performed with the mechanized Gas Tungsten Arc Welding (GTAW) process.
The SG nozzle ends and the existing elbows will be machined to a specific narrow-gap weld geometry.
The weld joints will be made using remote-controlled narrow-gap orbital welding unit.
The welds will be performed in a layer by layer technique and with constant welding parameters around the weld circumference. In case of differences in outside diameter, overlay welding could be carried out either automatically or manually, depending on the height of the weld built-up.
Due to the high quality of welds resulting from the optimized welding technique and the reproducibility of the mechanized process, the risk of defect is very low. However, repair welding procedures will also be prepared. Depending on the nature of the defects involved, either the mechanized remote-controlled GTAW process or a manual welding process will be used.

The welds will be ground (inside and outside the pipe) after completion. The following non-destructive examinations will be performed on the entire completed weld:

- liquid penetrant test (PT)
- X-ray
- Pre-service inspection ultrasonic test (UT)

1.3 Secondary and auxiliary piping, instrumentation and control, uprating related modifications

During the SGR, a lot of activities are performed on the secondary systems. The main ones are described below .

Main Steam System

Removal, for clearance purpose, of a section of main steam pipe for removal of existing steam generator and reinstallation, once new steam generator is installed.

Main Feedwater System

- Removal of the main feedwater elbow for clearance purpose
- Rerouting of the feedwater pipe to attach to the replacement steam generator nozzle (new location)
- Removal and reinstallation of the steam generator instrumentation pipe and tubing (clearance purpose and new instrument tap locations)
- Removal of the preheater bypass and warm-up piping and associated I&C (no preheater bypass required for the replacement steam generator)
- Replacement of the feedwater pump impellers and installation of larger capacity trim in feedwater control valves (higher feedwater flows and resulting increased pressure drops associated with the uprate require increased pump performance and control valve capacity)
- Relocation of the feedwater bypass control valves (to be used for startup and low loads)
- Operation with 3 FW pumps

Blowdown System

- Dismantling of the existing blowdown pipes inside the steam generator cubicle
- Installation of a revised blowdown piping in the steam generator compartment to balance the flow from the two blowdown connections provided on the replacement steam generator and to get a flow equal to 5% of nominal feedwater flow in the new piping at the connection with the existing piping (possible later modifications of BD system for higher flow, without any works in cubicles)
- Installation of vents at high points in the blowdown piping and provision of a connection to fill the blowdown system from the condensate system in order to prevent water hammer effect when restarting the system

Auxiliary Feedwater System

- Removal, for clearance purpose, of a section of auxiliary feedwater pipe for removal of existing steam generator and reinstallation once the new steam generator is installed
- Replacement of the auxiliary feedwater control valve trims to provide additional margin for AF pump operation

Heater Drain System

- Replacement of number 2 heater drain pipe from 12" to 24" (the existing pipe size is marginal for the required self-venting flow)

Condensate System

- Replacement of condensate pump suction pipe size from 24" to 30" in order to reduce pressure drop at uprate flows
- Operation with three CY pumps to provide adequate pressure at uprate flows

1.4 Multi-Purpose Building

Within the scope of activities for the Steam Generator Replacement, a Multi Purpose Building has also been included for the following purposes:

- storage of old steam generators
- storage of low and intermediate level waste from SG replacement
- decontamination area
- mock-up and training area
- personnel health physics area

The facility has been designed as a non-safety related building but calculated for non-collapse in the case of an SSE. Furthermore the radiation level at the site fence established in the Site Permit shall not be surpassed.

The design was performed according to the Slovenian construction regulations, for which purpose a PGD (design for construction permit) was generated, supported later on for construction purposes with the corresponding PZI (design for construction performance) documents.

For the licensing, the PGD was the basis according to the normal construction license which joined an assessment with regard to the nuclear application, having received in that way the construction permit.

The whole building is equipped with a nuclear HVAC system comprising a HEPA filter to avoid emission of radioactivity and to maintain a sub-pressure inside the building, as well as for personnel comfort. The decontamination area will be used for decontamination activities and is equipped also with a 5 ton crane. It also has a connection to the de-mineralized water system and an independent compressed air system. Radiation monitors with local alarms are connected to the control room and installed in the storage and decontamination rooms. The building will also serve as a storage place for the new steam generators during the winter 1999 / 2000. The new steam generators will arrive on site in September 1999.

2. Documentation for engineering and licensing

During the preparatory/engineering phase of the project numerous documents have to be prepared. There are mainly 4 categories of documents to be prepared by the Consortium:

- Document packages for permanent and temporary modifications. Besides all the design and design calculation aspects these documents include the safety evaluation screening and safety evaluation. These packages are the basis of the licensing process. After detailed review of these documents by NEK (by KOC-Krško Operating Committee and KSC-Krško Safety Committee) these documents will be forwarded to the URSJV (Slovenian Nuclear Regulatory Body). The methodology for licensing is in accordance with the US NRC (10CFR50.59) and also applicable to the domestic legislation (i.e. PGD documentation – documentation for construction permit).
- Documents for qualification of special processes, equipment and personnel
- Documents for procurement of temporary and permanent equipment
- Document packages for site implementation (installation packages)

3. Project organization and schedule

The Consortium project team includes Siemens located in Erlangen, Germany and Framatome located in Chalon, France. NE Krško also has a very good project organization in order to be able to react to the requirements of the project. For interface purpose the Consortium has a representative on site, during the whole engineering phase, who is also involved in dealing with Slovenian companies.

The shut down for the steam generator replacement starts on April 15, 2000. The replacement window is scheduled for a period of 28 days.