EXCHANGE OF STEAM GENERATORS IN PRESSURIZED WATER REACTOR POWER PLANTS

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ABSTRACT

As a result of problems experienced in particular in connection with the tubing of the steam generators, several utilities are having to replace their steam generators. Approximately 4 to 5 years before the scheduled replacement outage a feasibility study has to be conducted. In this study all site specific conditions have to be considered. As a result the optimum replacement method will be selected.

Following the study a detailed engineering and planning has to be done with focus on a step by step work sequence plan and in a two hours split up time schedule. Before starting the replacement work extensive training and qualification of personnel and equipment is unavoidable. Special technical features as

- optical survey
- mechanized cutting and machining methods
- remote controlled narrow gap welding
- specially developed decontamination methods

make sure that steam generator replacements can be performed in high quality within a short time schedule and with low dose radiation exposure.
As a result of problems experienced, in particular in connection with the tubing of the steam generators, several utilities are having to exchange their steam generators.

Besides the design and supply of complete replacement Steam Generators Siemens KWU Group performs all activities necessary for the replacement of these components. These activities are, essentially:

- Performance of studies, in particular of feasibility studies
- Performance of detailed engineering and execution planning
- Performance of personnel training and qualification
- Design, supply and qualification of special tools and equipment
- Procurement of the necessary hardware
- Performance of steam generator replacement on site.

All these activities can be performed as separate tasks or as a turnkey package.

1. **Feasibility Study**

   The feasibility study, as a rule carried out with a long lead time before steam generator exchange proper, investigates the following points:
   - Transportation of the steam generators out of and into the containment
   - Transportation and handling of the steam generators within the containment
   - Examination of the various replacement options possible
     - Replacement of a complete SG
     - Replacement of a split SG (steam dome cut, channel head cut)
     - Evaluation of possible reactor coolant pipe cut methods as they are essentially 2 cut, 3 cut, 4 cut method
   - Check of available crane capacity and of potential for modification
   - Identification of decontamination work possible
   - Comparison of options in terms of scheduling and economy

2. **Detailed Planning**

   Highly detailed planning is essential for completion of component exchange to schedule.

This requires an engineering schedule planning procedure to establish service activities such as:

- On-site walk through, including details as built templating and field surveying, during a plant refueling shutdown before commencement of exchange
- Identification of potential subcontractors
- Definition of deadline for ordering of all necessary hardware
- Development of a detailed engineering time schedule
- Preparation of review documents for hardware and for on-site implementation
- Preparation of a “general work sequence plan” for on-site implementation
- Personnel deployment planning
- Equipment deployment planning
- Design and qualification of special-purpose machines and devices as necessary
- Performance of calculations and analyses as necessary
- Performance of safety evaluations
Performance of dose rate calculations  
Development of shielding plans according to ALARA concepts  
Preparation of on-site time schedule  
Performance of on-site organization planning  
General management and follow up of all these activities

All these engineering and preparative activities are performed by a centralized planning team comprising specialists from the various engineering departments, as well as subcontractors working in close proximity. This makes for a short, efficient and rational engineering lead time.

3. Hardware

The hardware required for an SG exchange consists for instance of:

- SG hoisting equipment outside containment  
- SG hoisting equipment inside containment  
- SG transport facilities  
- Reactor coolant piping components, secondary side pipes, valves, pumps, supports, etc.  
- Insulation  
- Adaptation of existing machines and manipulators for machining, welding, decontamination, etc.  
- Models and personnel training and qualification facilities  
- General and special duty shielding  
- Infrastructure facilities like storage building; temporary access building; offices, etc.

All the above mentioned hardware has to be scheduled, designed, calculated as required, fabricated and delivered in such a way that it will be on site in due time before commencement of SG replacement.

4. Transportation and Lifting-In of the SG's

Removal of the old and installation of the new steam generators is essentially divided into three major phases:

- Transportation and hoisting outside the containment  
- Transportation inside the containment  
- Hoisting and turning operations within the containment

Special hydraulic cable jacks are used for this work. For work inside the containment, these special facilities can be used in conjunction with the reactor building crane or on the polar crane girders but independent of the reactor building crane.

The steam generators are transported into and out of the containment  
- through an equipment airlock  
- through the opening left when a material airlock has been removed (as it was conducted by Siemens KWU, when they replaced the steam generators at Obrigheim, West Germany, in 1983)
or via a transfer opening specially made to permit SG exchange and which must be closed again upon completion of SG exchange; (as it was conducted by Siemens KWU when they replaced the steam generators at Ringhals 2, Sweden, in 1989), and which of these transfer routes will be used will depend on local plant conditions and the exchange option selected.

5. **Measuring Technique**

Two techniques are normally used to record exact measurements above all in the area of steam generator supports and below the steam generators in the area of the reactor coolant piping:

- Photogrammetry and
- Optical measurement

The as is installed condition is normally measured by means of photogrammetry during a scheduled refueling outage and the results used as a basis for further planning.

Optical measurement is used for previous measurement on the new components (steam generators, reactor coolant line elbows) and for measurements during replacement operations. It will be used, for example, to establish the location of weld edges already prepared on the steam generator nozzles and on the remaining sections of the reactor coolant piping. These results will be then used as the basis for machining the elbow ends.

6. **Machining and Welding**

Machines specifically designed for local space conditions and application requirements are used for machining (cutting piping, weld-edge preparation, rounding-off pipe inside surface, outside weld surfaces, etc.).

These machines and devices can be suitably adapted for specific plant requirements.

An automatic GTA narrow gap welding process allowing relatively speedy, low-repair and fully remote controlled welding is used for the primary coolant piping. Here too, suitable equipment and the necessary expertise are available and can be adapted as required by the specific site conditions.

7. **Decontamination**

In order to keep the dose received during exchange work as low as possible, the parts to be exchanged, and especially the reactor coolant piping, must be decontaminated.

Depending on customer specification, this decontamination can take the form of decontamination of the entire primary system or of local decontamination of the SG primary heads and close-in parts of the reactor coolant piping before commencement of the first cutting work.
A further possibility - and this was used by Siemens KWU in their already performed SG replacements - is decontamination of the cut locations by electro-polishing or by mechanical blasting after cutting of the piping.

8. Personnel Training and Qualification

In order to ensure that work on site is performed smoothly and on schedule, major attention must be paid to personnel training and qualification.

A model designed specifically for this purpose is used to give the operating personnel hands-on experience, particularly in the following activities:

- Machining
- Welding
- Operation of the decontamination manipulators
- Optical/electronic surveying

A subsequent qualification program ensures that only well-trained personnel is used for component exchange in the power plant.

Prior to the personnel training and qualification program the same 1:1 mock-up will also be used for equipment qualification in order to make sure that all special tools and designed equipment fits according to the specific plant geometric requirements.

9. Siemens References in Steam Generator Replacement Worldwide

Feasibility Study

Beznau 1 (364MW, W) (1989 Transport Study of 2 SG's)
Ringhals 2 (860MW, W) (1987 Replacement of 3 SG's)
Angra 1 (650MW, W) (1989 Replacement of 2 SG's)
Doel 3 (392MW, ACEC) (1989 Replacement of 3 SG's)
Genkai 1 (559MW, MHI) (1990 Transport Study of 2 SG's)
Almaraz I and II (930MW, W) (1990 Replacement of 3 SG's)
Ascó I and II (930MW, W) (1990 Replacement of 3 SG's)

Detail planning

Obrigheim (345MW, KWU) (1982 Replacement of 2 SG's)
Beznau 1 (364MW, W) (Soft- and hardware planning for the Replacement of 2 SG's, each in two pieces, executed in 1985)

with Bechtel-KWU-Alliance:

North Anna 1 (915MW, W) (1990 Replacement of 3 SG's)
Palisades (750MW, C-E) (1990 Replacement of 2 SG's)
Farley 2 (828MW, W) (1990 Replacement of 3 SG's)
V.C. Summer (885MW, W) (1990 Replacement of 3 SG's)
Ginna (470MW, W) (1990 Replacement of 2 SG's)
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<td>Current projects</td>
<td>Beznau 1 (364MW, W) (Execution in 1993)</td>
<td>Doel 3 (392MW, ACEC) (Execution in 1993)</td>
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Ringhals 2 NPP, Sweden
SG Replacement
DE Austausch

Rigging of Steam Generators
Hebe- und Transportbewegungen der Dampferzeuger
Beznau Unit I, Steam Generator Replacement
Transportation of Steam Generator into the Reactor Building