Steam generators replacement at Doel 3 NPP (Belgium)

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The reasons that led to the conclusion that the most cost-effective strategy for the Doel 3 unit was the immediate replacement of the SG are presented. The paper evaluates advantages and drawbacks of the replacement techniques, the so-called 2, 3 and 4 cuts methods. It emphasizes the advantages of intensive use of computer aided engineering in this kind of backfitting. The methodology applied to combine a power uprating of 10% of the nominal power with the steam generator replacement is presented.

1) Why should the S.G. be replaced ?

As early as during the first operational cycle in 1983, an in-service leak due to PWSCC was detected at the 900 MW Doel 3 NPP.

Specific inspection techniques based on Eddy Current Testing were developed to monitor the problem.

Preventive methods were applied in order to "freeze" the disease status (shot-peening after the first operational cycle); repair techniques such as nickel plating and laser welded sleeving were implemented, specific plugging criteria were established, allowing the unit to be operated with a number of throughwall cracks while still meeting the leak limits of the technical specifications.

An integrated approach of the problem, including a prediction of the degradation rate, taking into account the cost of the inspections and repairs, the cost of the scheduled and unscheduled outages, the cost of the SG replacement and the possibilities of power uprating led, in 1989, to the decision to immediately replace the SG.

Specific requirements were included in the design specification of the new SG to avoid the various problems detected on former SG.

The tube material finally selected was peened Incoloy alloy 800 (Inconel alloy 690 was deemed technically equivalent).

2) How should the replacement be performed?

Several replacement techniques were evaluated. The 3 cuts technique associated with the "narrow gap" welding technique for the primary piping were eventually selected. This combination is the most time- and cost effective technique and ensures a minimum risk during the replacement operation : mismatches between the new SG and the existing primary piping can be dealt with by machining the new elbow; residual stresses in the primary piping due to piping displacements or weld shrinkage are minimized.

A global ALARA approach is applied during this project : all required operations are detailed using the Artemis schedule software. The time step of the schedule is reduced to 2 hours during critical phases of the replacement. This computerized scheduling system includes data related to the manpower required and to the location of the tasks to be performed, and is linked with a radiation dosis prediction system taking into account the evolution of the radiation level in all areas during the replacement operation (the radiation level prediction takes into account the impact of parameters like time between shutdown periods, installed shielding, removed equipment, etc.).

Risk management is included in the project management : the risk of each individual task is evaluated. Mock-ups are used to check feasability and duration of tasks that could impact the critical path of the replacement operations. Back-up procedures are established for these tasks, spare parts are ordered for important components.

3) Computer aided engineering applied to SG replacement.

C.A.E. can be applied in two steps :

- during the feasability studies : a detailed model is not required and C.A.E. is essentially useful for analysis of different options for the rigging of the SG and for clearances between the SG and the main structures;
- during the detailed replacement studies : provided a detailed model exists for all areas related to the replacement operation, C.A.E. is used in two main areas.

  1° The preparation of the numerous drawings related to :

  - rigging of the SG;
  - removal and storage of components;
  - protection of equipment to be installed;
  - addition of biological shielding;
  - location of cutting and welding equipment.

  These drawings can be efficiently achieved once the investment of coding the detailed model has been done.

  2° The control of component location during the replacement period.

The environment in a reactor building during a SG replacement changes frequently : components are displaced, scaffolding and gangways are installed and removed, various teams work simultaneously in many areas.

In order to keep the situation under control, all parts of the model that are moved during the SG replacement are coded in separated files, a link is made with the detailed computerized planning in order to determine where and when the corresponding part is located. This allows to have a forecast of the day by day environment in the reactor building (the software provides a "camera" that can be moved inside the model). The advantages that this system ensures in checking interferences, controlling the security aspects during the works and studying various possible options are significant.

4) How to achieve a 10% uprating?

A first feasibility study based on thermal hydraulic considerations showed that the new operating point could be 110 % of the nominal power. Above 10% of nominal power uprating, the associated costs would not be worth performing the uprating, major modifications having to take place in the B.O.P. (turbine, alternator, etc.).

The SGs were ordered with a rating of 110% of the actual nominal power, the heat exchange capacity being increased through diminishing the tube diameter (3/4" instead of 7/8") and through changing the tube pitch (triangular instead of square).

The detailed uprating studies were then performed in three steps, allowing to stop the studies, should the resulting uprating be deemed worthless :

- during the first phase, the most limiting accidents were analysed;
- phase 2 encompassed the safety analysis of all events influenced by the new operating condition;
- phase 3 includes the work necessary to update the technical specifications, safety analysis report and setpoints.