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PLANT NOMINAL POWER UPRATING OFFERS ATTRACTIVE POSSIBILITIES

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I. INTRODUCTION

Increasing the rated thermal power of an existing plant represents a particularly profitable way for a plant operator to increase electricity production. For PWR plants, a 5 % increase in power can, in fact, generally be achievied without significantly modifying systems and equipments based upon the margin in the original design.
Larger power increases can be achieved in the case of S.G. replacement. Based on recent analysis of a 3 loop PWR, 900 MWe, up to 12 % power uprating is feasible with an appropriate replacement S.G.

The general rule is to perform power uprating without significant increase of average primary temperature. This is mainly a result of consideration of S.G. tube corrosion, of fuel clad corrosion and of core safety margins (DNBR margins in particular).

This paper will present a general overview of the analyses for large power uprating : program of work, main conclusions on the following items :

- Safety demonstration (accident analysis, safeguard systems capacity verification, required protection setpoints modifications...)
- Normal operation review (possible consequences of power uprating on the plant maneuvrability and on the fuel management performances)
- Systems and components mechanical integrity review and potential effect on the plant lifetime of the new operating conditions.

After this general overview, the paper will to focus in section III on the possible plant lifetime impact of the power uprating.

II. POWER UPRATING ANALYSES GENERAL OVERVIEW

II-1 STUDIES TO BE CARRIED OUT AND MAIN CONCLUSIONS

The main areas to be analyzed are determined on the basis of an evaluation of the consequences of the new operating conditions on the plant behaviour (Figure 1).

II-1.1 Accident Analyses

- Increased power results in an apparent decrease in core safety margin with respect to design criteria (DNB, LOCA, linear overpower). A further analysis of the limiting accidents with respect to these criteria has thus been carried out, to determine the changes to be made to the setpoints of the protection systems, for instance the ΔT overtemperature and ΔT overpower trip channels, and also to the operating specifications. In order to maintain adequate operating margins, this analysis is carried out while using improved analysis methods and computer codes compared to those used in the original design.

  For the large break LOCA analysis the "better estimate" MEFRA-2 methodology is presently beeing used. MEFRA-2 includes the second generation TRAC-PF1 code for calculating the system thermal-hydraulic transient.

  For the DNB limiting accidents, a Generalised Statistical Method (MSG) is used for power uprating justification. MSG is a Monte-Carlo based method using a statistical combination of the uncertainties of the parameters influencing the DNBR.

The general conclusion of the analyses is that adequate Safety margins can be maintained without restriction on the fuel management performances (no need to decrease the Fq and $F_{\Delta H}$ power peaking factors).

II-1.2 Safety and auxiliary systems verification

The increase of rated power results also in a reduction in the margins concerning design criteria related to the mechanical integrity of the reactor coolant system and the secondary system (maximum allowable overpressure in particular). This reduction results from the more severe nature of accidents reducing the capacity of the secondary system to remove primary heat (loss of feedwater or of steam flow). The primary-side energy to be removed by the engineered safeguard systems, actuated under accident conditions (emergency feedwater, pressurizer and steam generator safety / relief valves, containment spraying, etc.), is in fact more important. A check has to be carried out to ensure that their functions are performed satisfactorily. The general conclusion has been that power uprating does not lead to any significant hardware modification of the above systems, mainly due to the oversizing and conservatisms of the original design (in particular use of over conservative decay heat curve like ANS 71).

II-1.3 Plant normal operation review

The analysis of normal transients has shown that the flexibility of the plant will be maintained, some setpoints of the main control systems have to be modified. A particular attention has to be paid to the full load rejection and to the reactor trip transients. A review of the plant operating documents is also performed.

II-1.4 NSSS systems and components mechanical analysis

The mechanical behaviour of the NSSS systems and components impacted by the new operating conditions is analyzed.

The analyses are performed in two stages :

1) Calculation of the new thermal-hydraulic conditions expected during normal transients or accidental conditions (in particular update of the

NSSS design transients, analysis of the hydraulic forces during a LOCA : on the primary loops, on the vessel and vessel internals and on the S.G., analysis of the subcompartment pressurization in case of primary or secondary break),

2) Verification of the mechanical integrity of the systems and components with the new thermal-hydraulic conditions determined in 1 (in particular fatigue analysis, structural integrity verification, reactor vessel embrittlement review).

The consequences of power uprating on the plant lifetime can be analyzed by the above analyses. This item will be developped in more detail in section III of this paper.

II-2 DESIGN PHASES

Is indicated in figure 2, a suggested approach is to perform the relevant analyses in three consecutive phases, including major milestones for licensing purposes.

Phase 1 : Feasibility studies

The questions to be answered during this phase are :

- Is Power uprating feasible without any major modifications other than S.G. replacement ? (if any)
- What are the potential minor modifications ?
- What will be the unit's new operating conditions ?

Phase 2 : Safety evaluation and design

This phase includes detailed analytical justifications for :

- FSAR limiting accident analyses, (core, primary system and containment integrity aspects)
- Detailed analysis of the necessary unit modifications.

Phase 3 : Implementation

This phase encompasses verification and updating of the Plant documentation, along with additional engineering work if found to be necessary during phase 2.

The mechanical review of the primary components is part of the Phase 3 work.

III. MECHANICAL REVIEW PLANT LIFETIME ASPECTS

III-1 MAIN ITEMS TO BE ANALYZED

Power uprating results in modified plant characteristics, which must be considered for the mechanical review. In particular :

- Impact of increased primary ΔT on the fatigue of sensitive parts of the reactor vessel (example : R.V. outlet nozzles) and of the R.V. internals (example : core barrel).
- Impact of the slightly decreased cold leg temperature and of the increased vessel fluence on the reactor vessel embrittlement risk.
- Impact of the slightly increased temperature difference between the pressurizer and the cold leg on the fatigue of the sensitive parts of the pressurizer (example : spray nozzle).
- Impact of the increased primary ΔT on the fatigue of the sensitive parts of the S.G. (example : partition plate in the channel head) and impact of the increased S.G. primary to secondary pressure difference on the tube bundle, tube sheet and partition plate (impact is

less critical in case of S.G. replacement).

- Impact of the new operating conditions on the plant transient behaviour. In particular, the affected normal conditions (category I) and upset conditions (category II) transients are reanalyzed. The updated transients are taken into account in the mechanical analyses. (Stress and fatigue analysis).

- Impact of the decreased steam pressure on the S.G. tube bundle vibration limit and steam moisture limit.

- Impact of the slightly decreased cold leg temperature on the LOCA hydraulic loads.

III-2 MAIN RESULTS

Power uprating requires checking the mechanical strength of the primary components :

- Reactor coolant piping, reactor coolant pump (RCP), reactor pressure vessel (RPV), reactor vessel internals, control rod drive mechanisms (CRDM) and pressurizer (PRZ), steam generator (without replacement)...

In order to select "sensitive" zones, for which the mechanical margins need to be re-evaluated, the existing stress analysis reports of the plant are reviewed. Selection of the sensitive zones is based on the stress range Sn and the usage factor U.

Once the sensitive zones have been identified, reevaluation of the mechanical margins is performed for these zones. The general conclusion of this reevaluation is that power uprating does not affect the mechanical strength of the sensitive components.

Several reasons can explain this conclusion :

- Generally, the changes of the design transients are not significant enough to yield unacceptable usage factors.

- In many cases, less stringent design assumptions can be adapted compared to the over conservative ones of the original design.

- Improved analytical methods can be used if necessary to compensate for penalyzing effects.

- Plant operation after power uprating can be modified to compensate for non-limiting events. For example, increased neutron fluence effect on the reactor vessel resulting from the nominal power increase can be compensated for by an improved fuel management strategy (low leakage type).

IV CONCLUSION

As indicated in Figure 2, Framatome has participated in several projects related to power uprating (with or without S.G. replacement) or to plant licensing bases analyses following S.G. replacement without power uprating but with modification of operating parameters.

It has been demonstrated that adequate Safety margins can be maintained even for a large power increase (with S.G. replacement). The other plant performance indicators like fuel management capability, plant maneuvrability are not impaired. In addition, power uprating does not lead to any significant effect on the plant lifetime aspects (except, obviously, the beneficial impact resulting from S.G. replacement).