

# UPRATING PLANS FOR THE SPANISH NUCLEAR POWER PLANTS

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The possibility of increasing the electricity production of Spain's current nuclear power plants might be materialised by increasing the originally licensed and authorised thermal power of the reactor, and also by replacing or modifying equipment in order to improve the efficiency of the conventional, non-nuclear part of the plant (balance of plant, BOP). In view of the high unit power levels of these installations, even a minor percentage increase in plant power leads to a substantial increase in overall output.

Increasing the rated electrical power has for some time been a strategic issue of interest for the Nuclear Power Plants (NPPs), this strategy being included as a priority course of action in the Spanish NPP Joint Action Plan.

## MOTIVATION AND EXPECTED BENEFITS

Increasing the electrical output of the nuclear power plants is of obvious economic interest for the Electricity Sector. The power increases currently contemplated amount to some 600 MWe for the period 1994-2003, over the 7,400 MWe installed, and further increases are foreseen as from that date.

It is estimated that somewhat more than half the 600 MWe foreseen may be obtained through moderate investments, as a result of which they will be highly competitive, while the remainder will require heavier investment, fundamentally in BOP equipment.

Furthermore, the electricity produced by such uprating of the plants will have a relatively low cost in comparison with

production by other energy means. The investments associated with the foreseen upratings are, in terms of pesetas/kW, lower than or comparable to those corresponding to alternative means of generation. In addition, the variable production costs would be lower than those of such alternative means since, on the one hand, they would arise as a result of improved plant energy efficiency (there would be no appreciable increase in fuel, operation or maintenance costs) and, on the other, there would be higher burnup of a fuel whose cost is relatively low in comparison to the alternatives. As a result, uprating the electrical output of the country's nuclear power plants would contribute to reducing the overall cost of the electricity generated.

It should also be taken into account that, from the point of view of energy independence, the contribution made by additional nuclear power will reduce the country's dependence on potentially more unstable energy imports. Likewise, it will minimise the environmental impact and social contestation that the request

for new sites inevitably implies, regardless of the type of fuel to be used.

## COURSES OF ACTION

As has been indicated above, two main paths are foreseen for plant uprating: increasing the thermal power of the nuclear reactor and replacing equipment in order to improve the performance of the non-nuclear part of the plant. The two are related, since no increase in reactor power will provide positive results unless the other plant equipment, for example the turbine or the alternator, is capable of handling it.

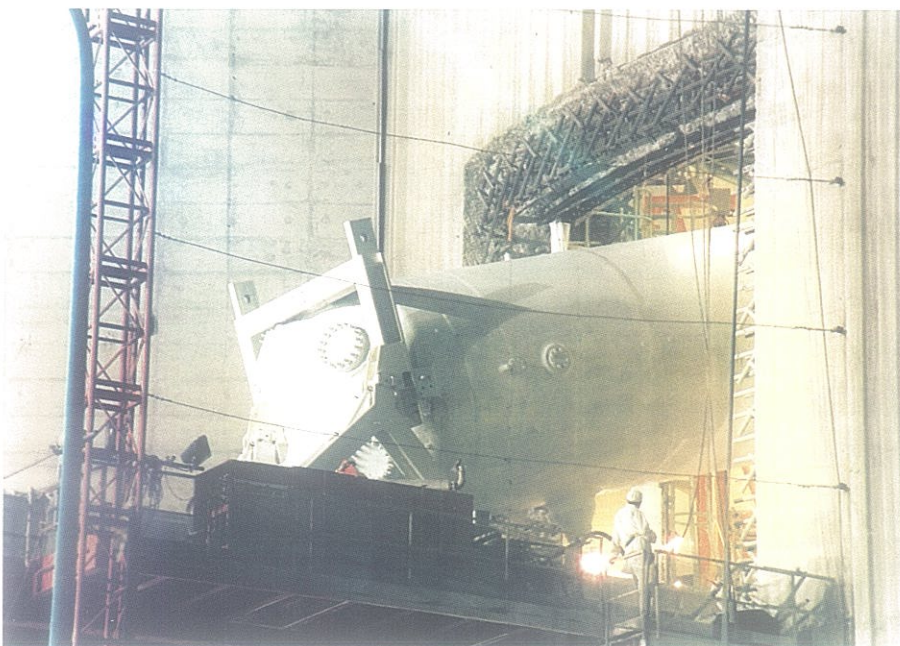
### Power uprating through improved energy efficiency

Increases in electrical output may be achieved by modifying or replacing equipment, thus improving the thermal output of the plant. The replacement of defective steam generators with others of a more modern design serving to

improve the quality of the steam, along with that of turbines, feed-water heaters and reheater/moisture separator tube bundles for more efficient equipment, allows higher levels of output to be achieved from the alternator for the same nuclear power and fuel consumption.

Such upratings in electrical power require approval by the Ministry of Industry and Energy (MIE). They may be complemented by a plan for the optimisation of on-site electricity consumption. Other possible increases over and

*Steam generators replacement at Almaraz NPP*



above those currently planned require more significant investments, and should be scheduled depending on the opportunities existing for such replacements (due to faults, loss of component efficiency or for other reasons).

It should be remembered that increasing rated electrical power has a special impact on the plant cooling systems, and that in some plants this will mean the need to increase their capacity.

In designing the components (steam generators, turbines, heaters, etc.) for the modifications and replacements that are currently being performed at different plants, or to be performed in the near future, consideration is given to potential power upratings, the new equipment being specified for an additional capacity of between 5 and 15% of the original design.

### Upgraded reactor thermal power

Increasing power output by uprating the reactor thermal power, following evaluation of the suitability and results of the corresponding feasibility studies, requires that a specific plan be developed for each plant. Generally speaking, this includes the performance of engineering and safety studies in relation to accident and transient analysis and to the analysis of fuel behaviour, as well as the performance of certain specific analyses relating to the specification of new equipment (where applicable) and the modification of existing equipments.

All the above is subject to an authorisation and licensing process which includes the drawing up of the report required for authorisation of the corresponding modifications and revision of the Final Safety Analysis Report and Operating Technical Specifications. The reports must be submitted to the regulatory body responsible for nuclear matters (Nuclear Safety Council, CSN) and to the MIE for approval and, where applicable, the recognition of the new electrical power level.

It should be pointed out that uprating the thermal power of existing reactors does not reduce the plant safety margins established in the original license, but rather that it is possible because of the better knowledge of nuclear reactor dynamics as a result of the continued R&D effort. Now more precise thermal-hydraulic, neutronic and mechanical parameters are incorporated into current calculation codes, which make more realistic (best estimate) predictions and verify the suitability of the available margins.

Consideration should also be given, when undertaking an uprating exercise, to possible synergies with other projects mapped out for the future or already under way at the plants. This analysis is important since there may be complex interfaces, new analyses or tasks common to the different projects, and their adequate scheduling may serve to avoid subsequent problems and extra costs. Among the examples of such other projects worthy of special mention are the reduction or elimina-

tion of plant scrams, the stretching out of operating cycles and the review of setpoints or analytical hypotheses.

### CURRENT SITUATION AND FORESEEN ACTIVITIES

The interest of the Spanish NPPs in uprating is a fact that has been manifested for some time and which has already led to the performance of different feasibility studies and/or to the implementation of different progressive power increases at certain plants.

In 1988 a 2% nuclear boiling ratio (NBR) increase was licensed and implemented at Cofrentes NPP, a BWR originally rated at 975 MWe, which has since then been operating satisfactorily at the new power level (990 MWe). Gradual increases in electrical output have been obtained at the Vandellós II and Trillo plants as a result of improved thermal output of the installations and, in the latter case, also due to a redesign of the turbine. More specifically, Vandellós II NPP uprated from 992 MWe to 996 MWe in 1991, and subsequently to 1,004 MWe in 1992, and Trillo increased in 1992 from 1,041 MWe to its current level of 1,066 MWe.

The table attached hereto shows the Uprating schedule that the Spanish NPPs have recently initiated or intend to implement in the near future.

It should also be taken into account that at present certain plants have not yet completed the feasibility studies corresponding to their intention to uprate nuclear power, or, having already implemented equipment replacements or modifications, have either yet to carry out the tests required for establishment of their new definitive power level or are awaiting recognition of such tests by the MIE. In this respect, the forecasts included in the aforementioned table may undergo deviations, in magnitude or date, due both to the final results of the studies and tests and to whatever effects might arise as a result of the future regulatory framework established for the Spanish electricity system.

In summary, the current forecasts as regards the respective uprating plans of the Spanish nuclear power plants are as follows:

#### José Cabrera NPP

At present the plant does not have the intention of uprating.

#### Santa María de Garoña NPP

During the latest refuelling outage (March 1996) this 460 MWe rated BWR plant increased its output by a few MWe as a result of improvements to the reactor water clean-up system. During 1997 the plant plans to update the feasibility studies performed previously with regard to uprating nuclear power, and will subsequently take its decisions on the course of action to be adopted.

#### Almaraz NPP

Almaraz NPP, with its two 930 MWe rated power PWR units, decided some time ago to replace its steam generators (SGs) and high (HP) and low pressure (LP) turbines. The studies associated with the improved quality of the steam provided by the new SGs and the greater efficiency of the HP and LP turbines point to an increase in electrical output per unit of 53 MWe, which would bring the power level of each such unit to 983 MWe.

During the second quarter of 1996, Almaraz-1 initiated replacement of its SGs and turbines. In 1997 Almaraz-2 will undertake this same process of equipment replacement, as a result of which its power level will reach 983 MWe.

The feasibility studies carried out for the plant in relation to uprating nuclear thermal power point to the possibility of an 8% increase (to 2,910 MWt), which would take the electrical output for each of the units to 1,040 MWe. These increases are foreseen for the years 2000, for Almaraz-2, and 2001, for Almaraz-1.

#### Ascó NPP

Ascó NPP has two PWR units of the same rated power as Almaraz. In 1995 Ascó-1 achieved a 17 MW increase in electrical output as a result of replacement of its SGs and of the HP turbine, going from 930 to 947 MWe.

In 1996, Ascó-2 replaced its SGs, HP turbine and LP turbines. This unit initially foresaw an increase in electrical output to 968 MWe, and is now provisionally operating at 966 MWe. Ascó-1 forecasts a 21 MWe increase in 1997 as a result of replacement of its LP turbines, going from 947 to 968 MWe.

The on-going studies consider an 8% uprating in nuclear thermal power (to 2,910 MWt). That would mean a 5.4% increase in electrical output which would be set at 1,020 MWe. These increases are foreseen for the years 1999, for Ascó-2, and 2000, for Ascó-1.

Consequently, the total power uprating (reactor+BOP) foreseen for each of the Ascó units as a result of the above amounts to some 90 MWe with respect to the respective initial design power levels.

#### Cofrentes NPP

In April 1996, this BWR plant submitted to the CSN the documentation required for a 105% NBR increase. This would mean an increase in electrical output from the current rated level of 990 MWe to some 1,025 MWe. Implementation of this increase is foreseen before the end of 1997.

Furthermore, the on-going feasibility studies consider that an electrical output of 1,120 MWe could be achieved in the year 2003, this power being limited by the currently installed alternator. Additional power increases might be achieved as a result of turbine-generator set replacement (LP turbines and alternator).

*Vandellós II NPP*

As from April 1996, this PWR plant has had a new recognised electrical output of 1,009 MWe, this representing a 5 MWe increase over the previous rating. This is the result of several factors including replacement of the feedwater control valve, increased condenser vacuum and a reduction in secondary-side losses.

A further increase of around 6.5-7% is foreseen in electrical output, which would take the plant from 1,009 to 1,080 MWe. This increase would be achieved by changing the HP and LP turbine rotors and by uprating nuclear thermal power by 4.5% (to 2,910 MWt), and is scheduled for implementation in 1999.

*Trillo NPP*

This plant plans to initiate feasibility studies and studies on the advisability of uprating at the beginning of 1997. Previous studies based on increasing primary circuit average temperature estimate an increase of around 5% in thermal

power for a 2.5 °C increase in primary temperature.

**CONCLUSIONS**

One of the most significant results of the uprating programme from the point of Spain's installed nuclear plant is that the electrical capacity represented by implementation of the programme is equivalent to the installation of a mid-size nuclear power plant (~600 MWe) or to a new conventional fossil-fired plant of a normal power level.

It should also be pointed out that, in economic terms, the necessary investment costs and kWh generating costs would be particularly attractive and competitive.

Power uprating actions will be even more interesting and justified in the upcoming more deregulated and more competitive electricity market. Improvements in efficiency and output along with generation cost reductions will be determining factors to succeed in such a competitive arena.



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**POWER UPRATING PLANS FOR SPANISH NUCLEAR POWER PLANTS**

| Year                                         | Date     | NPP<br>(-unit) | Initial<br>power [MWe] | Foreseen power<br>increase [MWe] | Reason                                                                      | New Power<br>[MWe] | Power<br>increase<br>in year<br>[MWe] | Installed nuclear<br>capacity at<br>the end of year<br>[MWe] |
|----------------------------------------------|----------|----------------|------------------------|----------------------------------|-----------------------------------------------------------------------------|--------------------|---------------------------------------|--------------------------------------------------------------|
| 1994                                         |          |                |                        |                                  |                                                                             |                    |                                       | 7,400                                                        |
| 1995                                         | Oct-95   | Ascó-1         | 930                    | 17                               | LP turbine change and improved steam quality due to new SGs.                | 947                | 17                                    | 7,417                                                        |
| 1996                                         | Apr-96   | Vandellós II   | 1,004                  | 5                                | Feedwater control valve replacement and reduction in secondary side losses. | 1,009              |                                       |                                                              |
|                                              | Sep-96   | Almaraz-1      | 930                    | 53                               | HP and LP turbine replacement and improved steam quality due to new SGs.    | 983                |                                       |                                                              |
|                                              | Oct-96   | Ascó-2         | 930                    | 38                               | HP and LP turbine replacement and improved steam quality due to new SGs     | 968                | 96                                    | 7,513                                                        |
| 1997                                         | Apr-97   | Ascó-1         | 947                    | 21                               | LP turbine replacement.                                                     | 968                |                                       |                                                              |
|                                              | Jun-97   | Almaraz-2      | 930                    | 53                               | HP and LP turbine replacement and improved steam quality due to new SGs     | 983                |                                       |                                                              |
|                                              | 3rd Q-97 | Cofrentes      | 990                    | 35                               | Reactor power increase to 105% and MSR improvements.                        | 1,025              | 109                                   | 7,622                                                        |
| 1998                                         |          |                |                        |                                  |                                                                             |                    | -                                     | 7,622                                                        |
| 1999                                         | Apr-99   | Vandellós II   | 1,009                  | 35                               | HP and LP turbine replacement                                               | 1,080              |                                       |                                                              |
|                                              | Sep-99   | Ascó-2         | 968                    | 52                               | Increase in reactor power to 104.5%.<br>Increase in reactor power to 108%.  | 1,020              | 123                                   | 7,745                                                        |
| 2000                                         | Mar-00   | Ascó-1         | 968                    | 52                               | Increase in reactor power to 108%.                                          | 1,020              |                                       |                                                              |
|                                              | Apr-00   | Almaraz-2      | 983                    | 57                               | Increase in reactor power to 108%.                                          | 1,040              |                                       |                                                              |
|                                              | 3rd Q-00 | Cofrentes      | 1,025                  | 15                               | Increase in reactor power to 115%.                                          | 1,040              | 124                                   | 7,869                                                        |
| 2001                                         | Mar-01   | Almaraz-1      | 983                    | 57                               | Increase in reactor power to 108%.                                          | 1,040              |                                       |                                                              |
|                                              | 2001     | Cofrentes      | 1,040                  | 27                               | Increase in reactor power 3%/year up to 1120 MWe.                           | 1,067              | 84                                    | 7,953                                                        |
| 2002                                         | 2002     | Cofrentes      | 1,067                  | 27                               | (See previous reason)                                                       | 1,094              | 27                                    | 7,980                                                        |
| 2003                                         | 2003     | Cofrentes      | 1,094                  | 26                               | (See previous reason)                                                       | 1,120              | 26                                    | 8,006                                                        |
| 2004<br>2005<br>2006<br>2007<br>2008<br>2009 |          |                |                        |                                  |                                                                             |                    | -                                     | 8,006                                                        |
| 2010                                         | 2010     | Cofrentes      | 1,120                  | 50                               | TG set change (LP turbines and alternator)                                  | 1,170              | 50                                    | 8,056                                                        |