THE SPANISH NUCLEAR POWER PLANTS SINCE 1982

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The article describes the evolution of Spain's nuclear power plants since 1982, the year in which the journal of the Spanish Nuclear Society first appeared, underlining those events that have had a special impact on this evolution at national and international level. At present, there are 9 nuclear groups operating in the country, of the total 17 that were at different stages of their life cycle at that time. This reduction in the number of groups that finally managed to initiate and indefinitely continue their operating lifetime contrasts with the growth of electricity consumption over the period, which has practically doubled.

During these 18 years there have been profound transformations in the social, economic and political context of Spain, both in general and in the Electricity Industry in particular. Nevertheless, there are now reasons, old and new, to feel confident as regards the future of this energy source.

One of the objectives of a professional association is usually to publish a periodical journal. If such a journal manages to reach its edition number 200, then the association in question may be said to have become consolidated, and the professionals involved to value, accept and support it. In the case of the professionals involved in the Spanish nuclear industry, this support has been demonstrated by the more than 1,000 articles that they have contributed to the journal of their Association, a publication that has proved to be a valuable mechanism for the exchange of technical information and a source of knowledge of national and international nuclear policy and strategies, acquired through the different interviews and editorials published.

Eighteen years have passed between the first edition of the journal of the Spanish Nuclear Society (SNE) and the issue 200, a period in which there have been profound changes in the Spanish Electricity Industry. Suffice it to say, in characterising this period, that we have gone from a situation in which 22 companies generated and distributed electricity within a framework of administrative concessions in which the State was the holder of the electricity service – and therefore ultimately responsible for the planning and approval of tariffs – to one in which 4 companies (plus others from abroad that are joining the system) operate on a liberalised market where the former subscribers, now customers, may freely choose their suppliers and negotiate supply prices with them.

Over these 18 years, the dimension of the sector has doubled, going from 93 TWh of annual electricity consumption at the end of 1981 to 185 TWh at the end of 1999, equivalent to an average cumulative growth of 3.9% per year.

In this article we shall tread the path taken by Spain's nuclear power plants during these 18 years, looking at what it was, what it might have been and what it has finally turned out to be.

The journal of the SNE came into being at a time when there was a temporary climate of optimism in Spain's nuclear fraternity, albeit threatened by forecasts of storms. At the beginning of 1982, shortly before the first edition appeared, there was little more than 2,000 MW of nuclear power connected to the national grid (José Cabrera, Santa María de Garoña, Vandellós I and Almaraz I nuclear power units), producing 8% of the total electricity generation of the country. A further 9,600 MW were under construction (Almaraz II, Lemóniz I and II, Ascó I and II, Cofrentes, Vandellós II, Trillo I and Valdecaballeros I and II nuclear power units), and 4,000 more (Regodola, Santillán, Sayago and Trillo II) with preliminary authorisation. In total, 18 nuclear units amounting to almost 16,000 MW of installed capacity had already made heavy investments under the auspices of the 1978 National Energy Plan (PEN-78), with an optimistic view of the future for this energy source.

Also in that year, the Statutes of the Nuclear Safety Council (CSN) were published, consolidating the operating system for an organisation commissioned to watch over the operation of the plants, an organisation which had become independent from the State Administration two years earlier, this pointing to the importance that this energy source was to acquire in Spain. An exception to this hopeful state of affairs was the assassination of Iberduero's top nuclear executive Angel Pascual that same year in yet another dramatic terrorist act against the two units of the Lemóniz plant, following the murder of the plant's general manager José María Ryan the year before, an event that caused a definitive crisis in the construction of the units when they were 95% and 75% finished, respectively.

The first issue of the journal "Nuclear España" (Nuclear Spain) was published in August 1982, during a period of pre-electoral campaigning and with certain parties announcing their proposals to reduce the nuclear plans, taking advantage of the electoral potential of the environmentalist groups that were then beginning to permeate Spanish society, as part of the political, social and cultural changes that were unfolding in the country. In October of that year, following the general elections, a socialist government took over and initiated a review of the aforementioned PEN-78.

The socialist Administration was highly critical of nuclear power, favouring domestic and imported coal. It also considered that the growth in electricity consumption assumed in the PEN

–4.7% per year– was excessive, and that the programme of on-going constructions (both nuclear and coal) mapped out would lead to a situation of overcapacity; in view of the high rate of investments, this would damage the financial health of the Electricity Industry.

In 1984, Parliament approved the PEN-83 plan, which covered the period 83-92, this having been drawn up on the basis of an annual increase in electricity demand of 3.3%. The PEN-83 plan concluded with the maintenance of coal-fired constructions and with a reduction of over 50% of the nuclear power in service foreseen in the previous plan, limiting it to 7,400 MW at the end of its period of validity. By that time the Regodola and Santillán projects had already been shelved, without even getting as far as the advanced engineering phase, and the Sayago project was pending its construction permit. This was finally not awarded, although all the main equipment had already been manufactured and was in storage. With this installed capacity objective, certain of the plants under construction would have to be removed from the equation. The PEN-83 plan spelled out a situation of moratorium for the Valdecaballeros I and II, Lemóniz I and II (already effectively paralysed by terrorist action) and Trillo II projects. The construction of this last unit, a replica of Trillo I, had not yet commenced and Valdecaballeros I and II were at that time at a point in their construction close to 70% and 50% respectively.

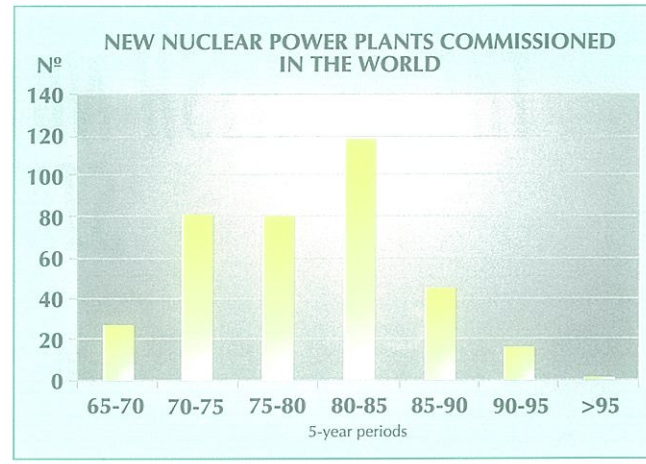
The construction and start-up of the Spanish nuclear power plants included in the PEN drew to a close in the second half of the 1980's, and were completed in 1988 with the entry into service of Trillo I. This was in keeping with a trend that could be seen at international level in the majority of the industrialised countries, which is where most of the nuclear programmes were being carried out. The following graph is eloquent in this respect.

During the latter stages of their construction or the early stages of operation, the units had to respond to important changes in the legislation and safety standards, resulting from the lessons learned from the accident that had occurred in unit 2 of the Three Mile Island plant in 1979, incorporating a large number of safety requirements additional to those that had existed when their designs had initially been drawn up. Those plants that were already in operation had to consider these changes in their Systematic Evaluation Programmes (SEP), required by the CSN.

This accident had caused a change in attitude throughout the international nuclear industry (first in the United States and subsequently in the rest of the world), with the individualistic attitudes that had characterised the construction phase evolving into one of mutual collaboration, the nuclear power plants now feeling themselves to be members of a community with common interests in relation to nuclear safety. It became clear that a nuclear accident in any part of the world was tantamount to its occurring throughout the entire world ("an accident anywhere is an accident everywhere"). The birth of the Institute of Nuclear Power Operations (INPO) as a result of this awareness was closely tracked by the Spanish plants, which decided that it would be appropriate to join its ranks as one of the first international members, accessing information on safety and operating experience of great interest, and providing their own in return.

The accident that occurred in unit 4 of the Chernobyl plant in 1986 initially created uncertainty regarding the possibility of new requirements. Finally, these were not necessary because of the major differences that existed between the safety criteria applied in the design and operation of western plants and those applied in the former Soviet Union. This accident globalised interest in international cooperation in nuclear safety, and led to the creation of the World Association of Nuclear Operators (WANO), to which the Spanish nuclear power plants have belonged since its constitution in 1989. Nevertheless, the accident created a concern among the public, a concern that was technically not justified but socially comprehensible, and the issue had to be addressed. In this respect, the journal of the SNE contributed with articles providing accurate information on the characteristics of the RBMK reactors like Chernobyl, different from western reactors, and on the radiological consequences of the accident.

The end of the decade of the 80's was marked by the accident at the Vandellós I plant -a fire in the turbine hall-, which led to a resurgence of concern about nuclear energy among part of Spanish society, a concern that was fed by anti-nuclear groups that rekindled the issue of the Chernobyl accident. The important and arguable new requirements that were imposed upon the plant for continued operation, along with the French Government's announcement that it planned to close the Saint Laurent plant, which was similar to Vandellós I, led the plant owner, Hifrensa, to take the decision to forego its operation. The Ministerial Order issued on 31st July 1990 left the third condition of the plant's Operating Permit, authorising power operation, without effect.



Following this decision, the Spanish nuclear industry in general, and the Electricity Utilities participating in ownership of Vandellós I as well as ENRESA, in particular, were faced with a situation for which there was a legislative gap. The scheduling of the decommissioning and dismantling activities for Vandellós I opened up a path towards bridging this gap, which was finally resolved in the new Regulations governing Nuclear and Radioactive Installations published in December 1999.

The end of the decade of the 1980's failed to regenerate in the Spanish nuclear industry the optimism that would have come from the lifting of the moratorium and the entry into service of certain of the nuclear units affected thereby. Nevertheless, 1990 was a year in which Spanish nuclear generation was consolidated, following the start-up of the last plants throughout 1988 and their initial phase of operation. Since then the Spanish plants have contributed an increasing annual production of more than 55,000 million kWh to the country's electricity production, and in the last years this has reached almost 60,000, a figure that has been exceeded significantly in the year 2000 and which represents a third of the total production. It was at the beginning of the 1990's that the plants

overall were fully in operation and were able to take advantage of the synergies provided by jointly addressing through UNESA common objectives in relation to operational safety and radiological protection for the personnel, the public and the environment.

But other matters requiring attention were now making themselves felt. The international trends towards opening of the electricity markets to a situation of competition, mapped out in Europe since the beginning of the 1990's in the drafts of the corresponding Community Directive – finally approved in 1996– made it advisable to optimise the average production cost of the nuclear kWh. Reducing costs was of transcendental importance if nuclear power was to compete with other energy sources. This reduction in unit costs would require intervention on its two constituent fronts, where the plant organisations have full power to act: increasing production and reducing Operations and Maintenance costs.

One way of increasing production without incurring excessive costs is by increasing electrical output. Consequently, and in view of the technological developments available, the Spanish Electricity Companies began to study the possible power upgrading processes that might be implemented. The different studies performed concluded that the electrical output of Spain's nuclear plants might be increased by almost 900 MW (say 12%), without any safety or technical reasons preventing it. On the one hand, the margins of the main equipment already installed allowed the licensed thermal power of the plants to be increased by between 5% and 10% (equivalent to a total electrical increase of 750 MW) while maintaining the safety margins contemplated at the time of licensing. Furthermore, there was the possibility of achieving increases in power by improving the efficiency of the main equipment involved in the cycle, especially the turbine, whose technology had evolved favourably in recent years. These increases were estimated to amount to a further 150 MW for the plants overall.

In view of these perspectives, the plants initiated a power upgrading plan that was implemented progressively throughout the 1990's. The application of this plan has meant that 500 MWe of the 900 studied are now a reality, this having implied an increase in installed capacity of 7%, and an additional 100 MWe are under way. Furthermore, there is the possibility for this total of 600 MWe yet to be increased by a few dozen MWe, so that final uprating will be close to 9%.

PLANT	INITIAL ELECTRICAL POWER (MW)	CURRENT ELECTRICAL POWER (MW)	INCREASE (MW)
José Cabrera	160	160	-
Garoña	460	466	6
Almaraz I	930	974	44
Almaraz II	930	983	53
Ascó I	930	1,028	98
Ascó II	930	1,015	85
Cofrentes	975	1,025	50
Vandellós II	982	1,082	100
Trillo	1,000	1,066	66
TOTAL	**7,297**	**7,799**	**502**

The advantage of this option compared to the construction of new electrical installations was, therefore, quite evident, since it allowed an important increase in production to be achieved without significantly increasing production costs. This increase in power is equivalent to placing in service a new, average-sized plant, and allows the annual contribution to the national grid to be increased by some 4,000 million additional kWh. This trend had already been initiated in other parts of the world. Countries such as Sweden, Switzerland and the United States have been authorising power upgrades at a substantial number of plants similar in design to the Spanish units, achieving increases of between 5% and 15% over the original design power level.

But the improvements in production have not been the result only of the power upgrading programmes. The reduction in the number of reactor scrams and in the time taken to return to power when such events occur, along with the shortening of refuelling outage times, have made it possible to progressively improve the plants' load factor, which now stands at annual average values of more than 85%, a figure difficult to exceed for a group of plants over such a long period.

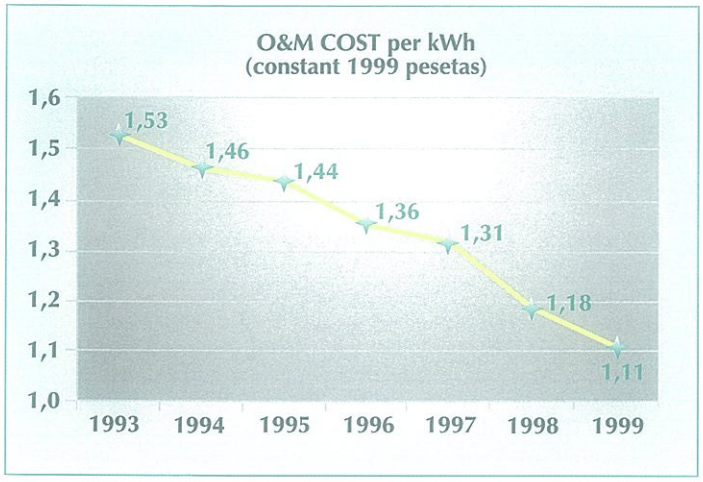
As has been pointed out, the second aspect to be considered is the reduction in Operations and Maintenance costs. With this aim in mind, improvements began to the management processes, mainly aimed at optimising the contracting of outside services, and at adjusting the size of the company payroll. These improvements, along with the increased production, led to nuclear electricity production prices in Spain attaining a privileged position from which to address free competition. O&M costs decreased progressively to 1.11 pesetas/kWh in 1999 (0.67 ¢e/kWh); along with a fuel cost of 0.65 pesetas/kWh (0.39 ¢e/kWh), this gave a net production cost of 1.76 pesetas/kWh (1.06 ¢e/kWh), on a market operating with generating prices of between 4 and 6 pesetas/kWh (2.4 – 3.6 ¢e/kWh). As a result, the nuclear power plants have become the cheapest power generating resource in the country.

The downward trend of the O&M costs over the last years can be seen in the following graph:

The second part of the 1990's saw an end to the uncertainties regarding the nuclear moratorium, with the publication of Law 40/94 on 3rd December. The plants under moratorium were definitively cancelled, and the corresponding regulations were issued. This Law was subsequently annulled and replaced by Law 54/1997 of 27th November, although this simply reaffirmed the decision already adopted by its predecessor. The Valdecaballeros I and II, Lemóniz I and II and Trillo II plants were definitively cancelled.

But the new Law brought new challenges: liberalisation of the Electricity Industry and the operation of the generating groups on a market of open competition in which electricity is offered daily, with only those plants whose prices are below the last required to cover the demand remaining in operation.

When this market began to operate, in January 1998, the nuclear power plants were well positioned to compete with other energy sources, a fact that has been demonstrated by their constantly being selected to operate at full power. Nevertheless, competition poses a continuous challenge that needs to be confronted, and the plants identified a series of possibilities for continued optimisation of their production costs, taking advantage of the synergies provided by unification or consolidation of management in certain cases. Organisational optimisation and plant lifetime management are two of the objectives that will allow the competitiveness of the nuclear power plants to be



improved. These policies are being adhered to also in other countries, with the United States being an outstanding example.

In the United States a rapid process of consolidation of nuclear operators is under way, underlining the high market value of nuclear power plants. The electricity companies with the largest numbers of nuclear units, and consequently the widest nuclear experience and most efficient organisation, are buying nuclear plants from others, generally companies operating a single nuclear unit, which are worse positioned to operate efficiently on a competitive market. This process is expected to reduce the number of operators from the more than 50 originally existing to no more than 10, which would make the 103 US nuclear units currently in operation even more competitive.

The beginning of the liberalised electricity market in Spain was accompanied by an event that constitutes a ray of hope for the future of nuclear energy in the world: the signing of the Kyoto Protocol in December 1997. The commitments acquired by the industrialised nations to reduce emissions of greenhouse gases must become one of the pillars sustaining defence of the nuclear option for the future. Nuclear power plants do not produce CO_2 or other greenhouse gases during their operation, as a result of which they constitute a powerful tool available to the governments for compliance with the commitments made at the aforementioned summit.

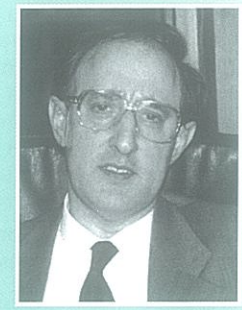
The World Energy Council has launched a message in keeping with this line of hope. "Keep all energy options open" is one of its 10 recommendations on political action to achieve the objectives of "energy accessibility, availability and acceptability" over the next two decades, as manifested in the document "Energy for Tomorrow's World- Action now" (April 2000). It should also be pointed out that nuclear energy is of fundamental importance since it is the only energy supply currently having extensive and widely diversified resources. It is practically domestic (because of the ease with which fuel for several years of production may be stored) and does not produce greenhouse gases. Furthermore, the document recognises that nuclear power is the only energy technology that might replace coal as a source of baseload generation if the threat of climate change were confirmed. It also recommends that the economic resources dedicated to nuclear research and development be focussed on the development of high power evolutionary (light water) plants and on inherently safe low power designs with the potential to penetrate the markets of the developing countries.

For its part, the European Commission is addressing the reality of the energy conflict in which Europe is immersed. For this purpose the socalled "DILEMMA Study" has been drawn up, in response to a request by the Commission, analysing the contribution of nuclear energy to the reduction of CO_2 emissions in electricity generation until the year 2025. The main conclusion of this study is that, even meeting the ambitious objectives for renewable energy sources mapped out by the Commission, and assuming a lifetime of 40 years for the nuclear power plants currently in operation, a further 100 such plants of 1,000 MW each would be necessary in 2025 to meet the Kyoto commitments.

Furthermore, the Commission has initiated the preparation of a document on security of supply, with the manifest intention of triggering open debate on the contribution made by the different energy sources to the future electricity supply of the European Union.

In parallel to the above, and in a more pragmatic fashion, the United States has reaffirmed the validity of this energy source by extending the operating licences of its current plants to 60 years, and the NRC has certified new designs, although for the time being no new constructions are being addressed.

At the beginning of this article I pointed out that the journal of the SNE came into being at a time when there was a temporary climate of optimism regarding nuclear energy, albeit with the threat of storms. Publication of number 200 of the journal also occurs at a time when there are reasons – old and new – to feel hopeful with respect to the future of this energy source, without which it would be impossible to meet the increasing electricity requirements of a world in which more and more countries are accelerating their economic development, a development that we all hope will be sustainable.



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In late 1981, he joined UNESA as head of the Electric Planning Department, and since 1990 he has been Director of the company's Nuclear Area.
He has been a Spanish representative on several Work Groups of UNIPEDE, OPEN and the IAEA, and he is currently a representative on the Nuclear Work Group of EURELECTRIC.
In late 1987, he became a Spanish representative on the recently created Committee headed by Lord Marshall to create WANO, and at the same time was elected Chairman of the Steering Committee in charge of organizing this World Association's Paris Center. He was Vice-President of the Paris Center for four years, and has been one of the nine members of the WANO's worldwide governing body for ten years. Since 1993, he has also been Chairman of the WANO Committee for improving the safety of Soviet-design nuclear power plants operating in Central and Eastern Europe.