THE NUCLEAR PROGRAMME IN SPAIN - SUCCESS FACTORS AND PRESENT ISSUES FROM AN ARCHITECT-ENGINEER's POINT OF VIEW

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SUMMARY

During 1989, the 10 nuclear units in commercial operation in Spain, having a total capacity of 7,838 MWe, supplied over 38% of the electricity generated in the country. With the exception of one gas-graphite reactor, presently shut down due to a significant fire in the turbine-generator, the rest are light water reactors - 7 PWRs and 2 BWRs. A further 5 units have been granted construction permits but are currently under government imposed moratorium due to an excess in generation capacity; construction for two of them however - namely the Valdecaballeros BWRs - is likely to be resumed in the near future. Although the NSSS design is imported from basically two sources - USA and Germany, the last two nuclear power units connected to the grid in 1988 have reached over 85% in local participation. As for the plants in operation, their performance indicators compare favourable with international standards.

From the perspective of an architect-engineering company, this paper describes some of the basic strategies and success factors of our nuclear programme and reviews some relevant issues presently being discussed or implemented by the nuclear industry in Spain.

OUTLINE OF THE SPANISH NUCLEAR PROGRAMME

In 1968, the first commercial nuclear power plant was brought into operation in Spain. In the two decades that followed, a further 9 units were added to the grid and construction for 5 more was initiated but has been temporarily halted and placed under government moratorium due to temporary overcapacity in the generation system. Therefore, there are presently 10 nuclear units in operation in Spain with a total installed capacity of 7,838 MWe. With the exception of one gas-graphite reactor, they are all light water reactors - 7 PWRs and 2 BWRs. During 1989, the 10 nuclear units - steadily operating at base load - produced 56,100 GWh, equivalent to over 38% of the total generated electricity.

The nuclear units constituting the Spanish programme are shown in the following table. They can be grouped into three generations of plants, corresponding to three well differentiated phases, not only chronologically, but also in contractual approach and resulting domestic participation.

	UNIT	CAPACITY (MWe)	REACTOR TYPE	NSSS SUPPLIER	COMMENCEMENT OF OPERATION
1st Generation	Zorita	160	PWR	W	1968
	Garoña	450	BWR	GE	1970
	Vandellós-I	500	GCR	CEA/EDF	1972
2nd Generation	Almaraz-I	930	PWR	W	1981
	Almaraz-II	930	PWR	W	1983
	Lemoniz-I	930	PWR	W	(1)
	Lemoniz-II	930	PWR	W	(1)
	Ascó-I	930	PWR	W	1983
	Ascó-II	930	PWR	W	1985
	Cofrentes	975	BWR	GE	1985
3rd Generation	Valdecaballeros-I	975	BWR	GE	(1)
	Valdecaballeros-II	975	BWR	GE	(1)
	Trillo-I	1041	PWR	KWU	1988
	Trillo-II	1041	PWR	KWU	(1)
	Valdellós-II	982	PWR	W	1988

(1) Plants under temporary moratorium

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Spanish utilities have retained the LWR technology for their nuclear plants. They have indistinctly constructed PWR or BWR plants, provided with either American or European NSSS design, depending on the specific technical and economic conditions offered by reactor vendors for each project. Each plant has been "one of a kind", different from the others. It appears today that government authorities and electric utilities are ready to change to a policy of standardization within a scheme of international collaboration that would keep open the possibility to choose the reactor type in future. Interest continues to be concentrated basically on LWR technology, either PWR or BWR. However, only one standard design would be used for each type of reactor as any plant site. This would provide both the benefits of standardization and the flexibility to select the best proposal from reactor vendors both from the economic and the technological points of view. Standardization is the challenge that awaits us for plants of the fourth generation.

TECHNOLOGY TRANSFER AND LOCAL PARTICIPATION

The three nuclear power stations comprising the first generation of units in the programme were contracted during the '60s under a turnkey contract drawn up for the entire plant with the NSSS supplier. Domestic participation in the construction of these units reached a value in the range of 42-44% of the total investment. The results insofar as transfer of technology was concerned were not altogether satisfactory either. However, the experience accumulated during this phase was useful in taking a new and better general approach to organizing the second phase of the programme.

The existence in our country in 1970 of an industrial infrastructure in full expansion coupled with a highly dynamic business environment, permitted the establishment of more ambitious targets for local content in the units to be constructed in the next phase. The following key decisions also contributed positively to the development of the second- and third-generation plants:

- Introduction by the government of a new policy decidedly favouring the increase in domestic participation

- Abandonment by the electric utilities of the "turnkey" approach in favour of contracting the plant "by components"

- Direct management of the project by the utility

This new organizational approach determined a significant increase in local participation for the second generation, reaching the value of 70-75%. The almost simultaneous commencement of 6 PWR and 1 BWR units in the second phase of the programme required the decisive mobilization of all engineering, manufacturing and construction resources available in the country to obtain rapid assimilation of technology and growing national participation.

The evolution of the nuclear projects in the third generation of plants has further consolidated the capabilities of the Spanish industry in the nuclear field to the extent that, although the NSSS basic design was imported from either the USA or Germany, local participation reached over 85% in terms of the total plant investment for the two PWR plants brought into operation in 1988.

PROJECT MANAGEMENT MODEL

As mentioned before, Spain's first three nuclear power plants were built during the '60s on a turnkey basis. For all the remaining units contracted since 1972, which are now either in operation or under construction, the contractual approach has been "by components", with the project developed under the direct management of the electric utility. Under this organizational model, the Owner established direct, separate contracts with the following main parties:

- With the Main Vendor, for the standard scope of the NSSS and Turbine-Generator only

- With the A/E company, for the engineering and design of the entire project and, in some cases, also for procurement, construction management and preoperational testing, depending on each particular utility

- With the various specialized material and equipment vendors, for the supply of BOP equipment and components, either item by item or in packages of homogeneous items, in compliance with the specifications prepared by the A/E

- With several construction contractors, for the civil construction and erection of mechanical, electrical and I&C systems

As it can be seen, with this direct management model the Owner maintains direct control of the design, procurement and construction process for the entire plant.

THE ROLE OF THE A/E COMPANY

To develop the project, the Spanish utility hires the services of an A/E company which carries out the engineering and design of the complete plant. The procurement, construction management and properational testing of the unit may also be assigned to the A/E company, or the utility may undertake this responsibility itself, depending on the resources or the managerial preferences of each particular owner.

Whichever the case, it should be understood that the A/E engineering and design scope will always cover the complete plant, performing (1) the detail design for the NSSS, based on the basic design for those systems supplied by the main vendor, and (2) both the basic and detail design for the BOP structures, systems and components.

The prominent role assigned to local A/E firms in the organizational structure of the Spanish nuclear programme has given rise to a strong A/E sector in Spain, following a pattern similar to that in the USA. This model is not usually encountered in other countries in Europe where the reactor and T-G vendors, together with large equipment manufacturers and construction contractors, have an extensive scope in plant engineering and design.

Today, virtually 100% of the engineering, design, procurement, construction management, preoperational testing and startup of the last generation of nuclear units in Spain, as well as support services to operating plants, is performed by Spanish A/E firms using local resources and capabilities. A/Es have implemented modern project management techniques and design practices. High-performance computers have been installed, and advanced computer-aided drafting, design and engineering capabilities are extensively applied both in new projects and in backfitting plants in operation.

The practice in Spain is that A/Es develop and integrate all project activities, from basic engineering to the complete detail design. Proliferation of contractors performing detail design activities as part of their fabrication or construction contract was progressively avoided as the nuclear programme advanced. It was found that the quality of the design could be impaired when using different design criteria, engineering solutions and project documentation. In our country, the practice now is that A/Es carry out the design and that contractors concentrate on manufacture, construction and erection.

From the perspective of an architect-engineering and construction company, the following is a summary of lessons learned in developing successful nuclear projects in Spain: (1) establishment of a flexible and clear organizational structure, (2) having a clear decision-making process, (3) use of simple and flexible project planning and control tools, (4) implementation of a computerized project information management system, (5) minimization of project interfaces, (6) establishment of an effective design change control system, (7) application of configuration management concepts, (8) expediting of vendor drawings, (9) advancing in detail design before starting construction, (10) keeping design ahead of construction, (11) procurement of material and equipment on time, (12) maximization of A/E detail design, (13) establishment of a strong detail design organization at site, (14) learning from the experiences of others - buying good ideas and developing them, (15) availability of information is essential, (16) experience feedback must be systematic, and (17) establishment of an ambitious training programme for engineers, designers and technicians.

CONSTRUCTION

Ever since the first generation of units, civil construction and erection of nuclear power plants in Spain has been carried out by local constructors. Construction management techniques that have proved a significant contribution to lower costs and time for construction are briefly discussed below.

The practice in other countries of using a prime contractor at site responsible for managing and carrying out construction and erection of the entire plant was not applied in Spain. Instead, use was made of a single, strong, independent Construction Management organization, capable of coordinating, supporting and supervising a large number of medium- and small-sized contractors at site.

A flexible contracting system was established by the owner, whereby certain large-scope construction packages (e.g. civil work, piping erection, etc) could be broken down into smaller, homogeneous packages commensurate with the technical, economic and managerial capabilities of each contractor. As construction progressed, or from one plant to the next, the scope of each contractor could be further adjusted to better match increasing or decreasing performance and/or capabilities.

Construction packages were preferably contracted by the owner on a unit price basis to facilitate scope modifications while maintaining the incentive of economic benefit. Under this approach each contractor was assigned overall responsibility for the technical aspects, quality, cost and delivery schedule within the established scope of work. Only when the scope of work was well defined in drawings and specifications were they requested to quote lump sum prices. Very little use was made of the cost plus method of contracting. Very little use was made of the cost plus method of contracting.

It has become common practice in nuclear projects in Spain, to establish an office at site to develop detail design and provide engineering support and advise to the construction and startup organizations. This office has decisively contributed to expediting the construction process when provided with capabilities and procedures to directly resolve and approve design deviation requisitions from those organizations.

PERFORMANCE OF OPERATING PLANTS

Using data corresponding to the 12-month period of 1989, the 10 nuclear units operating at that time in Spain had an average load factor of 81.5% and an average availability factor of 86.2%. For plants that operate on a 12-month fuel cycle, these performance indicators compare fairly well with international standards and can be considered to be the result of successful nuclear power development and utilization in our country. To reach these high performance levels, utilities have been focussing on activities such as the following:

Trip Reduction Programmes, with systematic evaluation of each unplanned reactor scram to identify the root causes and introduce modifications in operating procedures or design features to eliminate such causes. As a result, the number of unplanned scrams during 1989 averaged four (4) reactor trips per year

Heat Rate Improvement, establishing component and system efficiency surveillance programmes based on performance tests that use information from existent plant sensors handled by state-of-the-art data acquisition systems and specifically developed computer software packages to evaluate results and follow trends

Power Uprate, performing the necessary evaluations and analyses to support licence application for an increase in the unit power output. As a result of one such effort, the Cofrentes NPP, a GE BWR of originally 975 MWE, is now operating at a nominal capacity of 994 MWe

Component Diagnostics, to provide expert evaluation of current equipment conditions for early detection of any developing problem. It is worth highlighting rotating machinery diagnostics based on vibration signature analysis, Motor-Operated Valve (MOV) testing, on-line fatigue monitoring, and equipment diagnostics using thermographic detection techniques

Shortening of Refuelling Outages, having already reached a recorded minimum of just under 30 days

Other steps taken towards improving performance are (1) improved maintenance programme management, (2) QA programme for conducting plant operations, (3) strict QA/QC enforcement on equipment suppliers, (4) use of performance indicators for daily follow-up of most outstanding plant parameters, and (5) exchange of operating experiences among Spanish and foreign nuclear plants through INPO and UNIPEDE, as well as close contacts with similar plants.

SPENT FUEL RACK REPLACEMENT

In Spain, the storage of low-, medium- and high-activity waste is the responsiblity of ENRESA, a public company. ENRESA had planned and completed the conceptual design for a centralized, interim storage facility for all spent fuel generated in Spain until a site is developed for the final repository. However, due to the political difficulties in selecting a site suitable for that centralized, interim storage, a provisional solution has been adopted to extend current storage facilities as much as possible within the plant fuel buildings using reracking techniques.

The extension programme has begun in the Almaraz and Ascó Nuclear Power Plants, since they will be the first to use up their storage capacity. In due course, other units will follow suit. With respect to the recently awarded reracking project for the Almaraz NPP - a dual-unit, 930 MWe, Westinghouse PWR - it is envisaged that by 1991 the current fuel-pool storage capacity for 612 fuel elements will increase to 1,879 with the substitution of existing fuel racks by other high-density racks made of borated stainless steel. This threefold storage capacity will accommodate all the spent fuel elements produced until the end of the 40-year life of the Plant.

STEAM GENERATOR REPLACEMENT

Feasibility studies are being performed on the dual-unit, PWR-type Almaraz and Ascó Nuclear Power Plants for the substitution of model 51D steam generators supplied by Westinghouse. Tube corrosion problems, basically affecting the tube sheet zone, have made it necessary to plug tubes in spite of the preventive measures that have been taken, such as shot peening, sludge lancing and, in one case, the addition of a condensate-polishing plant.

In the case of the Almaraz Plant, not only is the actual substitution being studied, but also the possibility of achieving an estimated increase in unit power power of between 4-8% after generator replacement. Replacement in Unit 1 is expected to take place in 1996. The feasibility study considers the option of a generator in a single piece or in two pieces, and its insertion either sideways or through the dome. Either method would require a temporary opening in the containment. As for the type of new steam generator to be selected, the utility has decided to study the possibility of a design and supply different from the original one, as long as it is compatible with the design of the remaining plant systems.

PROBABILISTIC SAFETY ANALYSES

The use of Probabilistic Safety Analyses (PSA) as another tool to evaluate and imporve the safety level in nuclear plants took on an official status in our country in 1986 with the requirement by the National Safety Council that a PSA be performed for each operating plant. To date, four plants have initiated their PSA, Level I.

The characteristics of a PSA with multiple interrelated tasks make it necessary to carefully plan the activities and organization of the project if the objectives pursued are to be successfully accomplished. As key elements for such success, our experience indicates, (1) a clear definition of the objectives of the PSA to be performed, (2) availability of plant design and operation documents and data, (3) utility management commitment and involvement of plant operating personnel in the effort, (4) since the major portion of the Level 1 PSA is system analysis, it is essential that a solid group of mechanical and electrical system analysts participate, familiar with system design and operation, although they need not necessarily be familiar with PSA, (5) strong project management and integration of the various tasks of the analysis, and (6) good planning, clear methodology, an internal review process, and computer codes and tools to computerize the work.

Probabilistic safety analysis methodology permits the integration of both design and operation aspects (e.g. human factor) into a single assessment process and facilitates the weighted analysis of multiple failures with the objective of attaining a flawless, balanced safety project.

Deterministic methodology, on the other hand, is described in detail in a wide range of standards, making its application easier and essential in areas not subject to statistic or probabilistic processes. It is with these deterministic criteria that the regulatory authorities in Spain have authorized the operation of our plants to date. However, a significant change is taking place and probabilistic studies are currently required or accepted in the following areas: (1) risk assessment and probability of core damages (Level 1 PSA), (2) optimization of design improvements regarding their special application to plants (3) accident management to evaluate whether further measures are necessary, as in the case of the containment behaviour analysis in the event of severe accidents (Individual Plant Examination, IPE), and (4) optimization of maintenance and periodic testing activities.

Both deterministic and probabilistic techniques combine to provide complementary perspectives for maintaining the high degree of safety attained by the nuclear power plants designed according to the standards of Western countries.

LIFE EXTENSION OF OPERATING UNITS

Nuclear utilities in Spain have already recognized that the life of a plant may be prolonged beyond that originally expected and are, therefore, taking appropriate actions to justify life extension. Work in this area has already been initiated on one PWR and two BWR units. At present, the principal tasks being undertaken are:

- Developing criteria to select plant structures and components critical to life extension and establishing priorities for the work to be done in five-year plans

- Preliminary definition of degradation mechanisms and their indicators, supported by a plant inspection programme

- Identifying and compiling those original design, fabrication and testing documents, as well as those O&M and in-service inspection (ISI) records to be retrieved from the past and/or registered in the future to support the life extension option

- Establishing baselines and surveillance and evaluation programmes to assess the condition of structures and components, obtaining trends and establishing acceptance limits

- Establishing recommendations for changes to plant O&M procedures, and developing actions for improved maintenance, surveillance and ISI

Thus, the activities being developed are basically engineering evaluations and inspection and surveillance work, all in anticipation of actual life extension work which is expected to evolve during the next few years, once the regulatory policy and criteria for licence renewal have been established by the authorities. The objective new is to keep the life extension option open for the future while, at the same time, obtaining short-term benefits through improved plant O&M.

PREPARING FOR THE FUTURE

The economic development of our country requires a steady increase in electricity consumption over current figures which, in the medium-term, can only be reasonably obtained from two sources - imported coal and nuclear energy. Preliminary forecasts by the government prepared for the National Energy Plan, now under revision, indicate the need for new generating capacity by 1995 and a total of 7,000 MWe up to the year 2003. This being the situation, it is expected that resumption of work for the Valdecaballeros BWR units now under moratorium and half-way through construction will be authorized by the government. Additionally, projects for a further 6,000 MWe should be initiated before the year 2000, for connection to the grid by the beginning of the next century.

The experience with our operating plants is that nuclear power is safe, economical, environmentally clean, favours the balance of payments and allows access to high technology by local industry. With more than 38% of contribution to electricity production, nuclear energy is already a firmly established, economic reality in Spain. For these reasons, it is necessary to maintain the nuclear option open in our country beyond the completion of the units presently under moratorium.

Spanish electric utilities and the nuclear industry are already participating with other countries in international programmes to develop standardized designs for advanced light water reactors, which could be used in the next generation of power plants.