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EPR PROJECT CONSTRUCTION COST CONTROL

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ABSTRACT

The EPR project has entered the first phase of detailed design on January 1st,2000 for a period of three years. This phase follows the EPR Basic Design project managed by EDF and the GU's (German Utilities) with the support of FRAMATOME and SIEMENS. Common subsidiary NPI (Nuclear Power International) retained the principle of the evaluation of the costs of a construction of a nuclear island.

The EPR project is now managed by EDF in cooperation with the GU's. The main engineering activities for this period are related to the preparation of construction project management, deepening of some safety issues, definition of the project technical reference. The EPR project concerns the so-called reference unit, that is an isolated first-off unit, with unit electrical power of about 1500 MWe. The construction costs evaluated are those of the nuclear island, the conventional island, site facilities, installation work and the administrative buildings.

The EPR project construction cost evaluation method applies to all the equipment installed and commissioned. It requires the availability of a preliminary project detailed enough to identify the bill of quantities. To these quantities are then assigned updated unit prices that are based either on cost bases for similar and recent facilities or taken from request for quotation for similar equipment or result from gains due to contractual conditions benefiting from simplifications in the functional and technical specifications.

The input and output data are managed in a model that respects the breakdown on which the evaluation method is based. The structural organization of this method reflects a functional breakdown on the one hand (nuclear island, conventional island, common site elements) and on the other hand a breakdown according to equipment or activity (civil engineering, mechanics, electricity, instrumentation & control).

Controlling the evolution of costs is essential to the quality and credibility of the EPR project. Any event which might have an impact on construction cost, any deviation which may or may not be consecutive to a technical development is analyzed in terms of impact on costs, then formalized according to the project quality plan. The deviations identified and validated by the Project Manager will thus be observable throughout the first phase of EPR project detailed design.

This paper discusses the principle and the method of construction cost evaluation carried out, the cost data base and input and output parameters as well as results and oncoming cost analysis tasks .

1 INTRODUCTION

The competitiveness of the nuclear industry must be the result of drastic cost control measures as regards investment, fuel cycle, operation, maintenance costs taking into account *availability* of units and factor of load. Like any major industrial project, the economic control of the EPR project has applied the economic evaluation of the cost of construction of this project well upstream of the execution designs. Based on proven references like the N4 series and KONVOI series and the analyses from expert designers and manufacturers, the construction cost of the EPR project was estimated by applying the costing and analog assessment method, associated with the data base management model presented below. It is essential to note that project economic control is based on the continuing calculation of cost variances reflecting the result of project developments with respect to a well known reference.

2 BACKGROUND

In 1995, the NPI contract defined the principle of the evaluation of construction costs in the Basic Design phase of a nuclear island of the EPR power plant (joint Siemens – Framatome – EDFproject) whose production power was analog to that of the N4 and KONVOÏ (1450 - 1500MWe) series. While NPI was to provide the bills of quantities, EDF was responsible for the corresponding cost study of the Basic Design (100%BD) whose term was set for June 1997. Simultaneously EDF expanded the evaluation of construction cost of nuclear island to conventional island and BOP (balance of plant).

In order to meet the objective of a cost per kWh produced lower than that resulting from the 100% BD study, the power of the reactor was raised by 15% and in July 1997 an optimization study (115% BDOP) of the nuclear island taking up the same basic design as the 100% BD was conducted.

The start of the complementary 115% BDOP phase led to the extension of the cost study to early 1999 according to terms identical to those for the 100% Basic Design phase. Then, for reasons of technological limits (notably the generator), a return to a design (105% BD) corresponding to 4,500 MWth was decided keeping in the meantime the optimization options of the previous phase.

Simultaneously, the breakdown of N4 series costs yielded a cost data base called the N4 cost data base which throughout the EPR construction cost evaluation approach served as a reference for the input data of the EPR cost base. The main interest of the N4 cost data base is to provide the breakdown of the series cost of construction of N4 series and thus of associating a cost with a plant elementary component. The N4 reference has been used to date for the EPR construction cost evaluations.

Concerning the nuclear island, the EPR project assumptions in 1995 (100% BD) included the basic EPR options, a plot plan in C4D, that is containment surrounded by 4 buildings, the earthquake value retained of 0.25 g and the main components of the modified NSSS.

For the turbine hall, the EPR project assumptions in 1995 (100% BD) provided for a compact, simplified turbine hall, three main buildings, a 1800 MVA (Cos φ =0.9) generator operating under live load and motor-driven main feed water pumps.

As for the electricity and I&C domains, the EPR project assumptions in 1995 (100% BD) provided for 3 levels of voltage, four diesel generators and one optimized I&C system with four trains with little increase in automation and few technological developments compared to N4 series.

Regarding the BOP, the EPR project assumptions in 1995 (100% BD) specified one BTE (Waste Auxiliary Building) per unit pair, a cooling system whose technology is identical to Civaux (N4 series) and an SEC system (Essential Service Water System) including 4 trains in a closed loop of the same size as Civaux. The power transmission is the earth shielded subgrade type. Finally, the general expenditures and site installations are consistent with those of an N4 series.

The estimate of EPR project construction costs applies to a pair of units on a new riverside site with closed loop cooling whose execution provides for a series of ten units, or one unit per year. The lead unit and second unit are staggered by a few years.

Technical developments have occurred throughout the project notably in the search for optimization and yield new evaluations targeting global cost reductions.

3 EPR CONSTRUCTION COST EVALUATION PRINCIPLE

3.1 Construction cost evaluation method :

The evaluation method complies with that of major industrial projects based on a functional breakdown and on a breakdown per activity and equipment. That method applies to EPR project as well to N4 series and can be carried out whatever the nuclear project considered. The evaluation method here explained, enables to use the N4 cost data significant base by estimating cost differences in association with functional and EPR equipment compared to N4 series. EPR cost construction so estimated is termed objective cost.
At the launching of EPR 100%BD study, cost evaluations complied with expert advising. All along the Basic Design studying and the bill of quantities output, evaluations were pointed out during many evaluations phases. The expected results were indicated at miles stones called progress points.

During the EPR Basic Design and the optimization phase, the EPR project included seven progress points :

FILES OF SERIES COST CONSTRUCTION

Progress points		Output of core	Effects of optimization
0	(04/1996)	4250 MWth 100%	no
2	(06/1997)	4250 MWth 100%	no
4	(03 /1999)	4250 MWth 100%	no
6	(04/1999)	4900 MWth 115%	yes
7	(06/2000)	4500 MWth 105%	yes

The evaluation method is based on a functional breakdown on the one hand, that is per island and per functional plant system (Nuclear Island, Conventional Island, site common areas) and on the other hand on a breakdown per activity and equipment (Civil Engineering, Mechanics, Electricity, I&C). This breakdown is presented in a multi-level organization chart.

n 1	Islands
n 2	Buildings, System assemblies, Equipment
n 3	Plant components
n 4	Components requiring a more detailed breakdown

The N4 and EPR facilities at the beginning of the evaluation are broken down into up to 3 levels:

- level 1 corresponds to a global breakdown of the pair of units into a few items
- level 2 gives the titles of the evaluation sheets (sheets holding input and output data cf 4.1 and 4.2),

- level 3: inside each evaluation sheet considers the equipment seen from N4 data referring directly to the N4 cost data base. Level 3 is positioned at the level of the project players intervening on equipment and plant systems in the usual breakdown of the studies.

- level 4 is reserved for certain items like nuclear island piping for example. These equipments must be broken down in more detail (per line or section).

Quantitatively, the breakdown levels bring us to the following approximate figures:

Level	Average cost per item (MF/unit)	Average number of cost lines	Extrapolation
1	> 1000	4 to 9	no
2	180	50	no
3	30	300	yes
4	4	> 2000	yes

In practice, the extrapolations for the EPR are performed easily only on sufficiently broken down items (except at level 2 for the points not handled in the preliminary project).

Consequently in the case of the breakdown of the nuclear island, the organization is as follows:

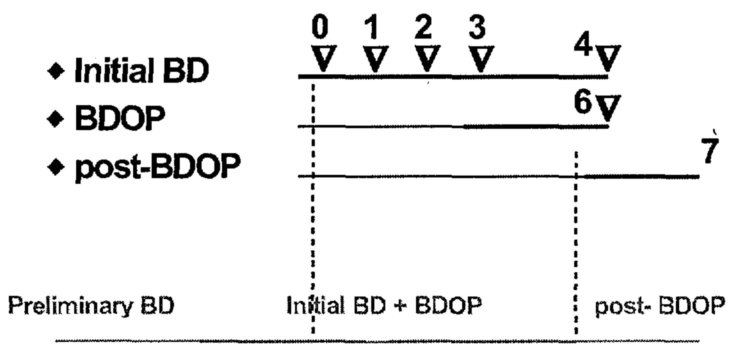
level 1	level 2	Level 3
NI	Building example	
	Main Bldg.	Main Civil Works Structural steelwork Painting Metalwork Doors Handling equipment Lifts and elevators Lighting Communications Ventilation
NI	Functional system example	
	Plant systems	Pumps Motors Exchangers Tanks

Each evaluation sheet has a perimeter that is determined according to the available N4 series cost data base, the major constraint being that after an extrapolation to the EPR, the entirely of the unit pair must be reconstructed with no omission or repetition. The use of plant systems in the level 2 breakdown, that is that of the evaluation sheets, is only useful for the nuclear island systems (about ten systems). The evaluations of the piping, valves, pumps, motors items grouping the equipment of nuclear auxiliary systems are obtained as a sub-product of the evaluations of each system. In the conventional island part, the breakdown remains at the Preliminary design stage, cost variances are obtained by allocating the technical differences identified to the different contracts. Generally, the information used in April 1996 to establish the objective cost is retained.

The development of bills of quantities, simultaneously EPR project and N4 series breakdown, to be able to have easy-to-compare elements is highly related to the development of the N4 Cost data base. The N4 data base was developed at the same time as the EPR evaluations. The N4 cost base is complete and has been totally operational to date.

3.2 Evaluation Phases

Phases of evaluation of the EPR Series cost of construction



Numbers indicate the progress points

- Phase 1: Start of 100% Basic Design. The level 3 evaluation sheets initialized at the probable cost are turned over to the experts by the project manager. The functional and material breakdowns appearing on these sheets correspond to progress point n° 3.
- Phase 2: the bills of quantities corresponding to each sheet are established; the EPR description at level 3, different from the N4 description, is detailed, the list of level 4 complementary breakdowns is provided.
- Phase 3: the cost items available and formalized by the experts are entered by anticipation in the EPR cost data base.
- Phase 4: End of 100% BD. Level 4 is created where necessary. The bills of quantities are known for N4 ; the modified functional systems are examined first. The results of the evaluation correspond to progress point n° 4.
- Phase 5: this is the Basic Design optimization phase (progress point n° 6 of April 1999) NPI has turned over the bills of quantities. The EPR elements are known and entered in the EPR cost base.
- Phase 6: this is the last optimization phase, that is the post-BDOP phase corresponding to an EPR sized at 105% but operating at 100% and evaluated on the basis of the 115% BDOP phase

3.3 Establishment of evaluation sheets and summary tables

The evaluation sheets contain the cost lines according to the functional and material breakdown retained by the project.These evaluation sheets and the technical-economic data contained in them are recorded in a software file that includes programmed links automatically generating the summary tables containing the results.

The project introduces the description of the functional and material breakdown and the bills of quantities communicated by the NPI contract. The sheets are then turned over to the sheet supervisors who transmit them via the cost correspondents to the technical experts responsible for allocating the unit prices either from the N4 cost breakdown or the unit prices from requests for quotes for identical equipment. Depending on the technical developments of the EPR project, cost extrapolations are made from the technical-economic data resulting from the N4 series. Each activity manager or sheet supervisor submits each completed evaluation sheet to the EPR project manager for validation before the data are entered in the EPR cost data base.

In order to facilitate the understanding of the origin of cost variances and to preserve the traceability of evaluations of each evaluation sheet, the latter contains the references of any type of document formalizing the technical-economic analyses by the experts.

4 EPR PROJECT COST DATA BASE

4.1 Data Base

The software program unites the 65 evaluation sheets containing the data resulting from the N4 cost data base, the EPR cost data produced by the trade experts, the associated comments and the references of the calculation sheets. Each cost sheet contains cost variances calculated between the objective cost of the EPR and the N4 reference cost.

Automatic links between the files and the summary tables group the result data in real time, like for example the cost variances in %. Several variance variables appear in the different progress points. These are the control items of the cost of construction of the project. The global variance summarizes the cost reduction efforts applying the analyses and technical assumptions.

4.2 Input data

- data resulting from the N4 cost data base
- EPR assumption data
- EPR bills of quantities
- unit costs
- EPR cost data from the trade experts
- the main observations related to technical developments
- the references of the cost estimate calculation sheets
- the economic conditions

4.3 Output data

- the estimated amount per plant elementary component
- the partial amounts according to the evaluation level. These amounts group several cost lines
- the variances per cost line
- essential comments
- the global variance of the EPR objective cost compared to the N4 reference cost
- the uncertainties

4.4 Example of an evaluation sheet

EPR	**Point 7 at end of BDOP**							Signatures
PTR		**Example of an evaluation sheet DFO**						Supervisor
C.E. 7/98								Correspondent
PTR (reactor cavity & spent fuel pit cooling & treatment system	1 unit	Series cost N4 unit		Comments on N4	EPR unit		EPR/N4 variance	EPR comments
		cost in MF			cost in MF		en %	
			sub-totals			sub-totals		
	Tank							no tank on EPR see IRWST
	Pumps (+ motors)			principal (*2x400m3/h*)				Increase of pump output for *availability gain - 2 x 1000 m3/hour -*
				other				
	Exchangers							Power exchanged: x 2 (in same temperature conditions)
	Piping			B4291				(0) same system to diameter (200 -> 400) : x 2 (1) 75 % instead of 100 % since ND 300 [FDC IN 96 841]
				in NAB				Building distribution with no significance for EPR
				IN SAB				
				in RB				
				in FB				
				common				
	misc. Valves							not identified N4 : 20 DN 200 EPR : 6 DN 400 - more smaller diameters total equivalent [IN]
PTR-EM	Total 1 unit							
PTR-CC	1 unit							
PTR-CC	total CC pair							
PTR	Total 1 unit CC included							
PTR	Total pair - CC included							

Note:

Gray - temporary

in italics: not broken down in N4 base

EM : Electromechanical

I&C:cabling control measures + I&C

Indicators

Diameter	1,75
Exchange	2

Range	up down		**Incertitude**	%

5 OPTIMIZATION OF COST REDUCTIONS: THE ECOREP APPROACH

ECOREP (ECOnomie des Réacteurs à Eau Pressurisée) (Pressurized Water Reactor Savings)

5.1 The origins of the approach

To maintain the nuclear option for the construction of new production resources open, the Operator's and Builder's motivations were particularly strong; this is the reason for the significant effort that was undertaken to improve the competitiveness of new nuclear facilities opposite the thermal production resources of other types, notably gas and coal. To reach this objective, the ECOREP approach was engaged to ensure the competitiveness of the current nuclear production installed base by controlling its maintenance costs and also to reduce the cost of construction of new plants.

In the framework of the EPR project, and in complement to the technical developments relating to an increase in safety and performance, studies aiming to apply the requirements of the nuclear industry to close the gap with good industrial practices in order to reduce equipment procurement costs were engaged. .

5.2 Purpose of the approach

Based on an Operator-Builder contract, the purpose of the ECOREP approach is to conduct studies aiming to propose a modification of the practices or recommendations applicable for the production of mechanical (notably outside the main coolant system and secondary system) and electrical equipment of PWR plant nuclear islands. The aim is to reduce investment costs while preserving levels of quality and safety equivalent to the preceding plants.

This work should yield modification proposals likely to be applicable in priority to the EPR project and if possible to the engineering and procurement of spare parts for plants in operation (900, 1300 and 1400 MWe series) and to possible export contracts.

5.3 The themes of study of the approach

- quality system
- supplier monitoring
- order file
- documentation required from suppliers
- revamping of RCC-E and RCC-M requirements (engineering and construction specifications)
- procurement and fabrication
- design and technology of pumps and valves
- mechanical construction codes
- piping applying the new earthquake approaches
- emergency generator sets
- selection of small electrical equipment
- electrical erection including cabling
- qualification of electrical and mechanical equipment

5.4. ECOREP approach results :

These study themes yield proposals for changes in industrial practices.

Estimations on expected cost reductions spread over electrical and mechanical equipments. As for those latter the analysis of cost reduction provided for splitting reduction gains as for instance regarding piping (equipment supplying, prefabrication and supports), valves, pumps, electrical motors, exchangers and tanks.

6 EPR PROJECT COST CONSOLIDATION AND CONTROL

Reference construction costs were consolidated for the last progress point, n° 7, at the end of BDOP for the EPR project. The cost of construction of a pair of EPR units with closed-loop cooling for a new riverside site integrates at this point of progress the ECOREP project optimization gains applied to the EPR project.

The gain values were entered in the cost data base via the concerned evaluation sheets.

The eighty-five cost lines included in the evaluation sheets show extremely clear traceability of the series cost variances between a pair of EPR units and N4 units; these cost lines facilitate the reading of cost evolutions. Consequently, during the first phase of detailed design currently in progress (from 1.1.2000 to 12.31.2002) the EPR cost base via the cost data base described allows efficient control over the project construction costs notably by applying the evaluations relating to any variance resulting from complementary studies.

7 CONCLUSION

The EPR project construction cost evaluation method applies to all project elements installed and commissioned. This method guarantees project cost control since it focuses on the control of cost variances of the plant components or systems.

The cost model used allows the full-scale application of the evaluation method by functional breakdown and breakdown per equipment family and automatically manages input data, notably the bills of quantities assigned with updated unit prices. It thus provides great flexibility of use for any update resulting from requests for quotes for equivalent equipment or from the necessity of including the cost reduction gains due to updated contractual conditions, that is contractual conditions benefiting from simplifications in functional and technical specifications and new industrial practices.

The first detailed design phase of the EPR project concerns the lead unit. It is evident that controlling cost evolutions is essential to the quality and economic credibility of this project. The EPR project method based on the analysis of and comparison to a proven reference on the one hand and on simple data base management software on the other forms a high-performing tool, an efficient decision system of value to the project manager. It guarantees real-time clear legibility of any variance and traceability of all variances linked not only to technical developments but also to those related to safety and engineering organization.