1. THE HISTORY

In the 1970's, Romania started an ambitious nuclear power program with the intention of building five nuclear power units at Cernavoda. To fulfill this program, the CANDU technology developed by Atomic Energy of Canada Limited (AECL), based on natural uranium as a fuel and heavy water as a cooling agent and moderator, was adopted. In December 1978, the CANDU technology procurement contract and other contracts were signed with AECL, through which the Canadians provided engineering and technical assistance, equipment and materials procurement from import, for the nuclear part of Unit 1. The services, engineering and procurement contracts were extended in 1981 for Unit 2. The site works started in 1980. In February 1981, a contract for the conventional part of Units 1 and 2 (the turbo-generator and its auxiliaries) was signed with General Electric (USA) and Ansaldo (Italy) companies.

The nuclear power program initially consisted of four power units of 700 MWe each, later, in 1982, it was extended to five units. Romanians managed the work on site, technically assisted by the Canadians and Italians while the State Commission surveyed the quality assurance and nuclear safety requirements for Nuclear Activity Control (CNCAN).

After 1989, the concept of the project development changed. Studies to establish the energy development and reorganization program concluded that completion of Cernavoda Power Plant was a necessity. Work was restarted under the new conditions, by implementing a thorough program of control, checks, and reparations for all previous work.

In July 1990, upon approval of the technical-economic study, the Romanian Government issued Decision No.750 for the project of “Cernavoda NPP 5 x 700 MWe”. Also in 1990, a PRE-OSART mission invited by the Romanian Government, representing the International Atomic Energy Agency (IAEA), inspected the Cernavoda site. The mission made recommendations and suggestions, among others, to transfer the project management to a specialized company, highly experienced in nuclear plant construction.

As a result, in August 1991, a new contract was signed between the Romanian Electricity Authority (RENEL) and AECL – ANSALDO Consortium (AAC) to speed up and complete works on Unit 1. The object of the contract was to permit a take over of the management of work on Unit 1 from RENEL by the Consortium (AAC), to complete commissioning and to operate the Unit under foreign authority for an 18 month period. Also in 1991, to conserve financial resources and focus effort, it was decided to continue work only on Unit 1, temporarily discontinuing work on the other units. Until 1998, only preservation and some remedial and progress work were performed at Unit 2. Unit 1 was successfully put into commercial operation on December 2nd, 1996, and on September 30th, after one year and 10 month of operation, has an availability of about 85%.

2. UNIT 2 STATUS IN 1991

Unit 2 status in 1991 was as follows:

a) The design was complete and approvals required for 1991 construction were obtained from the regulatory authority.
b) About 70% of the equipment and materials, worth about 545 millions US $ were procured as follows:
   • 206 mil. US dollars import (mainly from Canada and Italy for NSP and Turbine Building);
   • 49 mil. US dollars import from General Electric (USA, for turbine generators);
   • 290 mill. US dollar local supply

c) Construction erection progress: 25%
   • 65% civil: main buildings and structures erected; only some internal structures, repairs and finishing to be completed;
   • 15% mechanical: few equipment (calandria, steam generators, pressurizer) and piping installed, mainly in turbine building;
   • 3% electrical and I&C

3. ECONOMIC JUSTIFICATION OF THE DECISION TO COMPLETE UNIT 2

To support the decision to complete Unit 2, Cernavoda a re-evaluation of the project was initiated:
   • a detailed assessment of the Unit 2 safety design guides, design requirements and engineering design solutions in the light of changes in codes/guides/standards/actual regulatory requirements;
   • identification of changes possible to implement, to meet the actual technological and regulatory requirements;
   • Unit 2 cost/benefit analysis to demonstrate the economic efficiency of the project; and
   • inputting costs for all electricity generation alternatives (nuclear, coal, hydro-carbon, hydro), versus forecast electricity demand into the “Least cost power and heat generation capacity development study” to select the best development plan for the Romanian utility.

3.1. Assessment of the Unit 2 safety design guides, design requirements and engineering design solutions in the light of changes in codes/guides/standards/actual regulatory requirements

A joint team RENEL-AECL-ANSALDO performed this evaluation, considering:
   • Cernavoda Unit 1 as the reference for licensing, design, construction, organization of the project;
   • Experience during construction and feedback from commissioning and operation of Unit 1;
   • Experience from other Candu 6 NPPs in construction and operation;
   • Actual codes and standards; existence on the market of the original equipment suppliers; their availability to provide support (repair, spare parts); equipment obsolescence (especially on electrical and I&C; e.g., station computer, power centers, shut down systems panels, control equipment etc);
   • Current Romanian regulatory requirements.

To define the design applicable to Cernavoda Unit 2, we have used Unit 1“as built” documentation frozen at 30.06.1997, amended with a number of necessary changes identified or to be identified to be implemented and assessments to be done.

Significant specific issues of this activity are the following:
  a) Assessment of the effect of aging on the existing equipment and structures.
  b) Compliance with new AECB Canadian regulatory guides for containment, shut down, emergency core cooling systems and with reporting requirements for CANDU NPP (Wolsung 2-4 experience was used). All design changes implemented by AECL to upgrade Candu 6 design, taking W-2 as reference, were available. This list was revised and
design changes for licensing and safety requirements were assessed for Cernavoda 2. In this assessment, design changes to ensure full compliance with AECB guides were considered and implementation proposed where feasible.

c) Applicable editions of the safety guides/standards/codes: it is required to use the latest editions except for ASME 1971, 1974 and 1980, and for ANSI 1971, 1979 and 1980 editions, as applicable.

The safety guides will be revised based on AECL experience with W2-4 to reflect AECB requirements with restrictions imposed by the project status;

To ensure compliance with 1989 Canadian standards, NSP systems have been reviewed in detail. This review did not lead to important design changes; in most parts, the latest revisions of CSA standards establish actual industry practices, or there was enough conservatism in the design to comply with more restrictive requirements. Because it is impossible to review the design for a revision date later than 1989, we would consider the following approach:
- the design will comply with the 1989 revision of Canadian norm and standards;
- the equipment already procured will meet the requirements of the standards in force at the time of procurement; and
- all new equipment will be procured in compliance with 1989 codes and standards, or more recent revisions.

d) Assessment before commissioning for common utilization of the water from the dousing bay and medium pressure stage of ECCS, common civil structures for Units 1 and 2 and compliance with single fault criteria defined for equipment:

Considering the tight completion schedule and cost restraints, we asked the regulatory authority for a deviation from the requirement to accept the completion of these assessments later, based on the safety philosophy used and accepted for Unit 1.

e) Evaluation of plant behavior during severe accidents (over design base accidents):

The expertise is unavailable. This requirement will be addressed as part of the long-term development plan, in cooperation with other Candu owners and in correlation with funds available.

f) Completion of level 1 PSA for all plant systems for nominal power, partial load and shut down status including external events before commissioning.

PSA level 1 for nominal power without external events will be produced and used like a good tool for design package verification. The rest will be addressed as part of the long-term development plan, in correlation with funds available.

g) A program accepted by the Regulatory Authority to prepare PSA level 2 and 3 in time for submission of the application for operation of Cernavoda Unit 2;

This requirement will be addressed as part of the long-term development plan in cooperation with other Candu owners, in correlation with funds available.

h) Assessment of the compliance with ISO 9000 for some manufactured equipment.

i) Total replacement of BOP analog/digital control system with a distributed control system.

j) Replacement of the station computers.
Improvements to the display/annunciation system in the plant control room, as well as greater attention to the ergonomics and human factors. Improved construction sequencing to shorten the construction schedule.

3.2. Unit 2 cost/benefit analysis to demonstrate the economic viability of the project

To evaluate the capital cost required to complete Unit 2, all activities were identified to put Unit 2 in commercial operation: engineering, procurement, construction, project management, training, insurance, administrative and social requirements. Physical quantities applicable to the reference project and cost were assigned to each.

a) Engineering activities:
   - Incorporating Unit 1 implemented modifications if applicable, in the Unit 2 design;
   - Engineering work due to equipment obsolescence; and
   - Producing the construction and safety design packages.

b) Procurement evaluation: the assessment balances material and equipment deemed necessary and with that already available from the original procurement for Cernavoda Unit 2, with the addition of equipment identified by the preservation group as unsuitable for use.

c) Construction assessment: man-hours required to erect the necessary physical quantities, based on approved Romanian Labor Standards, adjusted for local labor conditions and the experience gained during construction of the Unit 1. Ten per cent of the estimated construction time was added to deal with the envisaged non-conformities.

d) Training: Cernavoda NPP has a training center equipped with a full-scope simulator which, together with Unit 1 under operation, sets the necessary premises for the staff dedicated to Unit 2, providing adequate training according to international standards. The scope of work will represent the foreign instructor man-hours.

e) Insurance: includes the Construction All Risk (CAR) and the Nuclear All Risk (NAR) insurance.

f) Administrative and social costs to cover:
   - an office building for project operations;
   - refurbishing existing offices;
   - refurbishing of the existing town site; and
   - transportation facilities

g) Project management: mainly the manpower required on site to manage the project (site engineering, construction, procurement, material management, planning and scheduling, finance and administration), both Romanian and foreign specialists.

h) For each change required for implementation to meet the actual technological and regulatory requirements, an evaluation is performed to identify cost and schedule impact.

Capital cost to complete and put in operation Unit 2 is the sum of the above costs

3.3. Unit 2 cash flow analysis

A cash flow model has been developed. The financing scenario provides that all resources will be from loans, NUCLEARELECTRICA providing only interest during construction.
Results of the analysis show that Cernavoda Unit 2 is economically feasible. However, capital cost is a constraint that, if exceeded, may significantly decrease economic viability. A key factor is the ability of the owner to introduce competition into the procurement, management and construction of the project. Recent developments in the capital market put additional constraints on the economic efficiency.

3.4. Least cost power and heat generation capacity development study

In parallel, selection of the best development plan for the Romanian utility has been contracted to SEP - EDF - Tractebel consortium for the “Least cost power and heat generation capacity development study” based on construction and generation costs for all electricity generation alternatives (nuclear, coal, hydro-carbon, hydro), versus forecast electricity demand.

For 750 MUSD, capital cost to complete Unit 2, the least cost study shows that Cernavoda Unit 2 is the option ranked first. Sensitivity analysis shows that even for a higher than expected forced outage rate (15 versus the expected 8%) or for a higher (about 15%) than expected capital cost, Unit 2 remains attractive.

4. THE CHALLENGE FOR AN ADVANCED FINANCING SCHEME

In light of the extremely difficult conditions prevailing in the financing markets during the past few months, developing viable financing alternatives for the Project is a real challenge.

4.1. Risk analysis

A key issue for a successful financing plan is risk allocation. The risks in technology, construction, operation, fuel and heavy water supply, safety and licensing regulation and power sales have been considered.

Candu is a well-tested and mature technology. There are a lot of similar power plants in operation with satisfactory service records. Unit 1 in operation, with good performance records, represents a strong base of knowledge for the construction of Unit 2. We presume that the constructor will assume all risks associated with construction.

As Unit 2 operator, Nuclearelectrica is responsible for the achievement of a minimum annual production to generate necessary revenues to reimburse the investors.

Based on Unit 1 experience, the Romanian manufacturers for nuclear fuel and heavy water are expected to supply for Cernavoda 2.

To overcome potential problems, we intend to clearly follow all the requirements of the Regulatory Authority before re-start of the works.

Nuclearelectrica will sign a power sales contract with CONEL to carry out transmission and distribution of electric energy. The possibility that CONEL will collect the bills and limit the enterprise arrears is a problem still to be addressed.

4.2. Potential financing schemes

To develop a viable financing structure, different alternatives must be considered, including: public markets, banks (syndicated loan), export credit agency (ECA), private placement and strategic partners.
Assessment of market conditions for these alternatives shows:
- the capital markets are extremely difficult without a sovereign guaranty;
- country limits are a constraint;
- financing with a major ECA depends on an upturn in Romanian and Eastern European markets generally;
- investor appetite for nuclear risk is limited;
- many key institutions are not interested or are restricted from investing in nuclear projects;
- investors require a premium return relative to either public markets or strategic partners; and
- a limited number of potential partners.

Most likely the final financing scheme will combine these alternatives to minimize, as much as possible in the actual framework, the State sovereign guaranty and the financing costs.

5. CONCLUSIONS

The completion of CERNAVODA Unit 2 is no doubt, an ambitious and challenging undertaking. The viability of the Project, under certain circumstances, has been analyzed and is strengthened by the following:

- The Project is grounded on a very positive background and environment, considering efforts of the Romanian Government to develop a comprehensive nuclear power program, the work already carried out and the infrastructures effectively in place. The best utilization of these infrastructures, with Unit 2 completion, will have a substantial positive economic impact on the operating costs of CERNAVODA NPP.
- The Project, viable in the light of Romania’s Least-Cost criteria, might assume greater importance for the larger geographical area, considering the well-recognized urgency to shut down, as soon as possible, some older and un-safe nuclear power plants operating in neighboring countries.
- The main potential participants have successfully cooperated in the realization of Unit 1, and therefore, there are good premises for an effective organization to complete Unit 2 in the most favorable conditions concerning costs, technological performance and timing.

REFERENCES