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Nuclear New Build - Requirements Beyond the Technology

I. Introduction

World Nuclear Association projections show a requirement for about 250 GWe of new nuclear generation by 2030. This represents a competitive marketplace for vendors - with requirements for new plants going beyond the design technology alone, as utility generators seek to minimize risk and maximize return on investment. These requirements include:

- proven, economically-competitive product;
- innovative business model;
- successful project model with assured on-time, on-budget delivery;
- high operational performance and maintainability;
- ongoing plant and technology support.

Atomic Energy of Canada Limited (AECL) has been successfully building CANDU®* nuclear power plants for more than 40 years. With a proven team, AECL is ready to deploy its Advanced CANDU Reactor®*, ACR-1000®* [1-4], to meet future customer needs. The basic design is completed and the ACR-1000 is in project mode, applying the techniques that contributed to the impressive schedule accomplishments in building CANDU 6 units at Qinshan Phase III in China. The ACR-1000 is a generation III+ product with a comprehensive, proven technology pedigree, offering distinctive economic, performance and safety advantages.

AECL is closely involved in current new-build initiatives relating to the ACR-1000: technology assessment in Ontario, feasibility study in New Brunswick, and site licensing being prepared in Alberta (all in Canada). Additionally, the ACR-1000 has been chosen for generic design assessment in the United Kingdom. AECL is also negotiating for a CANDU 6 new build in Argentina and is actively pursuing prospects in Romania and Turkey.

2. Proven product

The ACR-1000 has been developed by AECL from experience and feedback gained in the design, construction and operation of CANDU 6 reactors operated by 10 utilities around the world. The ACR-1000 is a 1200 MWe-class nuclear power plant with a 60-year design life. It is a light-water-cooled, heavy-water-moderated pressure-tube reactor, which has evolved from the well-established CANDU line. And 90% of plant features, equipment and

specifications are based on the CANDU 6 reference plant. The ACR-1000 retains basic, proven, CANDU design features while incorporating innovations and state-of-the-art technologies to ensure fully competitive safety, operation, performance and economics.

PROVEN CANDU STRENGTHS RETAINED:

- modular, horizontal fuel channel core;
- simple fuel bundle design;
- separate low-temperature and -pressure heavy water moderator;
- passive safety features including reactor vault filled with light water surrounding the core and two independent, passively-driven, safety shutdown systems;
- on-power refueling;
- reactor building access for on-power maintenance.

KEY ACR-1000 INNOVATIONS:

- more compact core design;
- steel-lined, 1.8-metre thick containment building, to withstand aircraft strike;
- light water reactor coolant, reducing heavy water inventory and resulting in lower costs and reduced emissions;
- use of low-enriched uranium (LEU) fuel, in advanced CANFLEX®*-ACR fuel bundles, to help achieve negative void reactivity;
- capability to efficiently burn other fuel types such as mixed oxides (MOX), thorium and actinides;
- further enhanced engineered and passive safety [5];
- four-quadrant design: essential operating and safety systems separated into four divisions; permits on-line maintenance, flexibility during outages;
- customer-driven improvements in operability and maintainability, with designed-in maintenance features;
- distributed control system/plant display system; modern control centre incorporating human factors;
- improved plant performance through SMART CANDU®* advanced on-line diagnostic systems.

These technical improvements, along with system simplifications and advances in project engineering, manufacturing and construction, result in a reduced capital cost and construction schedule, while enhancing the inherent safety of the ACR-1000 design. All innovative features of the ACR-1000 have been or will be fully tested

and proven before the first project. Because of this, and incorporation of successful features of existing CANDU technology, the initial ACR-1000 project will be executed with a high degree of confidence.

The design-basis lifetime capacity factor for the ACR-1000, over the operating life of 60 years, is greater than 90%, and the design-basis year-to-year capacity factor is greater than 95%. The high average annual output is achieved by a low forced loss rate of less than 1.5%. AECL-designed and -built CANDU 6 units are already achieving a lifetime capacity factor of 88.1%, and the combined average for 2006 was 92.4% in 2006. And the newer Ontario Power Generation and Bruce Power multi-unit CANDU stations are operating impressively, with annual capacity factors in excess of 90%.

3. Innovative business model

Historically, the station owner assumed most, if not all, of the risk in nuclear power plant projects. In a future new-build project, dependent on agreement with the owner, AECL would be responsible for project management, design, Nuclear Steam Plant (NSP) engineering, NSP procurement, Balance of Plant (BOP) engineering and equipment, construction, site project management and site commissioning management, with a commitment to fixed in-service dates. AECL would subcontract work as appropriate.

The owner's scope typically would include providing financing, site, administration and other ancillary structures, training, commissioning and operations staff, licensing and permits for project and operation, nuclear safeguards, and heavy water and fuel (although fuel may be under a separate contract with AECL).

In 2006, Canada's leading private sector companies in the nuclear and power plant field -Babcock and Wilcox Canada, GE Canada, Hitachi Canada and SNC-Lavalin Nuclear Inc - joined together with AECL to create Team CANDU®*. The team has developed a positive, long-standing relationship through the success of several previous new-build projects. Team CANDU is also supported by associate members, including the Organization of CANDU Industries (OCI) - which provides active, robust and efficient project support for equipment supply - and municipalities, labour groups, universities and clean air groups.

4. Successful project model

Primary factors leading to AECL's successful project performance have been:

- on-going engagement in new-build projects by AECL and its key partner, SNC Lavalin Nuclear Inc (formerly Canatom)

and now Team CANDU, thus maintaining experienced core project management capability;

- proven supply-chain base of internationally-renowned manufacturers and suppliers of nuclear and conventional equipment and materials, to ensure highly competitive pricing and delivery terms;
- long-term commitment to developing and continuously improving specialized project management tools;
- effective, proven project management systems;
- use of modern software, including CADDSS for reactor design and 3-D modelling of complex construction sequences, and Primavera P3 for project management scheduling, as well as proven materials and wiring management systems;
- maximum use of modularization and "open-top", parallel, construction - demonstrated at Qinshan Phase III - significantly reducing schedule and contributing to quality performance;
- cooperative management style successful in dealing with diverse partners and customers.

AECL has had a successful project history dating back decades. Projects have ranged from new-build turnkey to completion of Cernavoda units 1 and 2 in Romania. The last five new-build CANDU 6 projects were completed on or ahead of time, and on or under budget.

WOLSONG PROJECT, SOUTH KOREA

Wolsong CANDU 6 units 2, 3 and 4 were completed in 1997, 1998 and 1999, respectively. AECL, as prime contractor to Korea Electric Power Company (KEPCO) for the Nuclear Steam Supply System - utilizing the services of two major Korean subcontractors, Doosan for Local Equipment Supply and the Korea Atomic Energy Research Institute (KAERI) - performed the engineering, design and supply of the NSSS for a firm price.

As architect engineer for the Balance of Plant (BOP), AECL - through its Canadian subcontractor CANATOM, and its Korean subcontractor KOPEC - performed the BOP engineering and design and procurement service for a reimbursable price, subject to maximum man-hours. Local manufacturing was a key consideration for the project and reached 70% for units 3 and 4. The project was completed on schedule and on budget.

QINSHAN PHASE III, CHINA

The Qinshan Phase III project, completed in 2003, comprised two CANDU 6 units. A "paperless" project, it demonstrated new construction technology such as "open-top" construction and modern engineering tools. Financing was a requirement, and AECL, through its own efforts and those of its major subcontractors (selected for their ability to bring financing), was able to deliver to the customer a

complete financing offer through their home country export credit agencies.

AECL, as turnkey contractor for the project, was supported through major subcontracts for:

- construction, by Chinese construction contractors;
- BOP design and supply, by Hitachi-Bechtel consortium.

The owner, Third Qinshan Nuclear Power Company (TQNPC), directly managed the BOP construction program and provided staff for commissioning under AECL's direction. Shanghai Nuclear Engineering Research and Development Institute (SNERDI): on behalf of the owner, provided the BOP construction management team.

Unit 1 was completed under budget, and 43 days ahead of schedule; the unit achieved in-service 54 months after first concrete. Unit 2 was also completed under budget, and 119 days ahead of schedule. This delivery performance has enabled the industry to overcome the public perception that nuclear projects often exceed their budget and schedule.

CONSTRUCTION STRATEGY

The main elements of AECL's ACR-1000 construction strategy - proven at Qinshan Phase III - are:

- open-top construction method using a very-heavy-lift crane;
- parallel construction;
- modularization and prefabrication, as opposed to "stick-built" sequential construction;
- use of advanced engineering tools.

The open-top/vertical installation construction method provides schedule flexibility and significantly reduces installation time while improving quality. It ensures an uncluttered work environment, reduces labour requirements and allows work access from the top and bottom simultaneously. The internal structure of the reactor building is initially built as vertical walls without floors. Major modules - about 120 for the ACR-1000 - are then installed in parallel.

5. Improved operations and maintenance capability

The design-basis lifetime capacity factor for the ACR-1000 is greater than 90% over the operating life of 60 years, and the year-to-year design-basis capacity factor is 95%. This performance is based on the proven track record of AECL-designed and -built CANDU 6 units, which have collectively surpassed the US and French LWR capacity factors with a combined average of 92.4% in 2006, and a lifetime capacity factor of 88.1%. Also, the newer Ontario Power Generation

and Bruce Power multi-unit CANDU stations are operating well, with annual capacity factors in excess of 90%.

For the ACR-1000 design, CANDU plant operators provided feedback on improving operability and facilitate maintenance. This has allowed new features to be designed into the plant to reduce operating risk. As well, the traditional outage of up to one month has been improved for the ACR-1000 to one planned outage every three years, with a duration of only 21 days. This is largely made possible by designed-in on-line maintenance.

Operability-enhancing features in the ACR-1000 include advanced computer control and interaction systems [6-8] based on human factors engineering, enhanced power manoeuvring capability to simplify reactor operation and make the ACR-1000 inherently more responsive, and provide station blackout capability, ensuring a rapid return to full power on restoration of the electrical grid.

Other aspects of the ACR-1000 operations- and maintenance-based design include:

- improved, long-life materials and experience-based plant chemistry specifications;
- integrated SMART CANDU technology [9] to provide on-line system health monitoring and diagnostics;
- on-power maintenance strategy;
- improved plant layout, with a permanent elevator, walkways and platforms and provision for electrical, water and air supplies built in for on-power and normal shutdown maintenance;
- effective on-power reactor building accessibility;
- computerized testing of major safety systems and automatic calibration of in-core detector control systems;
- increased shielding in radiologically-controlled areas, reducing worker exposure and occupational dose.

6. Ongoing plant and technology support

The ACR-1000 is an evolutionary design and enhancements have resulted from extensive AECL efforts in code validation and R&D on reactor and fuel design and materials properties, as well as operations and maintenance input provided through the CANDU operating plant network, the CANDU Owners' Group (COG). AECL's comprehensive R&D facilities at the Chalk River Laboratories remain instrumental to the success of the new Generation III+ ACR-1000 and continue to provide assured on-going support to operating CANDU reactors worldwide.

AECL's CANDU Services group is also committed to current CANDU plants and provides products and services to ensure operating CANDU reactors continue to outperform

the competition. Both R&D and services functions provide assurance of ongoing plant and technology support into the future.

7. Conclusion

Now and in the future, nuclear power will play a major role in providing a safe, clean, reliable source of electricity. Station owners are looking to a proven Generation III+ plant, with innovations maximizing safety, operational performance and maintainability, to deliver this promise. Additionally, owners are seeking a business model that minimizes risk while maximizing profit, and a vendor with recent, proven experience who has delivered projects on time and on budget. As well as initial performance, those same owners need assurance of a long-term commitment to ongoing technical and maintenance support.

AECL has been successfully building and supporting nuclear power plants for more than forty years. Supported by Team CANDU, and with a fleet of top-performing CANDU 6 reactors around the world, AECL and the ACR-1000 will meet or exceed utilities' needs and expectations.

8. References

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