LIGHT WATER REACTORS FOR THE 1990s AND BEYOND — THE US PROGRAM

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Abstract

A national program is underway to ensure the availability and future viability of the Light Water Reactor (LWR) in the United States. Using utility requirements derived from experience with over 100 operating U.S. LWRs, new LWR designs are being developed with improved safety, reliability, maintainability, and compatibility with the environment. A large size LWR standardized plant is to be certified by the Nuclear Regulatory Commission by 1991, and one or more mid-size passive plants by 1995. Supporting programs for improving plant construction and providing protection from severe accidents are also being conducted. Finally, a national effort is underway to extend the operating lives of existing LWRs, thereby providing a substantial contribution to the Nation's electric needs.

INTRODUCTION

The economic and national security of the United States (US) requires a diversified energy supply base built primarily upon adequate, domestic resources which are relatively free from international pressures. Nuclear energy is a vital component of this supply and is essential to meet current and future national energy demands. It is a safe, economically competitive, and environmentally acceptable option that continues to contribute to our Nation's energy stability, security, and strength.

The light water reactor has been a major and successful contributor to the electrical generating needs of many nations throughout the world. It is being counted upon in the United States as the key to revitalization of the nuclear energy option in the 1990's.

In recent years, the Department of Energy (DOE) joined with the industry to ensure the availability and future viability of the light water reactor option. This national program has the participation of the Nation's utility industry, the Electric Power Research Institute (EPRI), and several of the major reactor manufacturers and architect-engineers.

The major objectives of these coordinated activities are to:

o formulate requirements which must be met by future light water reactor designs;

o resolve, through interaction with the US Nuclear Regulatory Commission (NRC), major open issues applicable to the safety of future US nuclear units;

o demonstrate an improved regulatory process by certification of standardized advanced light water reactors by 1991;

o design, develop, and certify standardized and simplified advanced light water reactors with passive safety features by 1995; and,

o ensure that the national resource of more than 100 operating light water reactors is not prematurely lost due to arbitrary licensing periods.

ADVANCED LIGHT WATER REACTOR (ALWR) PROGRAM

This program develops and obtains certification by the Nuclear Regulatory Commission (NRC) of improved versions of light water reactor technology suitable for deployment in the years ahead. The ALWR Program comprises major segments managed by EPRI and DOE. The EPRI work has a very strong utility orientation, with policy and technical guidance provided by a Utility Steering Committee of senior, experienced nuclear utility executives. The ALWR Program is growing in national and international prominence, and now involves participation on the part of segments of the Far East and European nuclear industry.

Three fundamental standards must be met before the advanced light water reactor can be considered a viable candidate for U.S. utility investment. First, it must be an excellent powerplant in all respects. This includes safety, foremost, but must also embrace all of the criteria by which real powerplants are measured, including reliability, maintainability, and compatibility with the environment. Secondly, it must be economically attractive in comparison to its alternative fossil-fired units. Finally, and of particular importance for nuclear plants, the advanced light water reactor must provide very high protection of utility investment, in terms of predictable construction costs and schedule, assured licensability, predictable operating and maintenance costs, and very low risk of severe accidents. In short, the investor must have extremely high confidence that the high capital cost of a nuclear plant is warranted.

To achieve these basic acceptance criteria in the ALWR, the Utility Steering Committee adopted several important design principles which have guided the work since its outset. These are:

o Simplification - the ALWR is to be substantially simplified compared to existing plants o Margin - the ALWR is to be a rugged, forgiving design

o Proven technology - the ALWR will apply the best experience of existing plants

o Human factors - the ALWR design will be sharply focused on the man-machine interface, serving the needs of the operators responsible for its safe, efficient performance

The main ALWR task areas are:

o definition of the technical requirements for advanced light water reactors;

o demonstration of the efficacy of the standard plant licensing process by certification of one or more large (1250-1350 MWe) evolutionary advanced light water reactor standard plant designs; and,

o development and certification of greatly simplified mid-sized (about 600 MWe) light water reactors that employ predominantly passive safety features and modular construction.

ALWR Requirements Document

This task involves the generation of detailed requirements for future LWRs. There are over 100 operating nuclear plants in the United States. These plants constitute an extraordinary experience base from which compelling conclusions can be drawn regarding both desirable and undesirable design features. Notwithstanding plant-to-plant variations, the overall performance of U.S. nuclear plants has been good. Specific regulatory guidelines, plant operator training methods, and specific hardware designs have evolved based on these existing reactor systems. For all these reasons, a logical and high-success approach for the ALWR program is to examine carefully this existing technical basis and to develop an ALWR design which is an evolutionary improvement or refinement of the existing design base. Industry appropriately has had the lead in this effort.

The Electric Power Research Institute's efforts pursue this course in developing a set of specific and detailed design requirements for an evolutionary ALWR, for both BWR and PWR designs. In each case, the design concepts, systems, and hardware specified are conventional in nature, but they employ the ALWR principles outlined above. For example, a PWR designed to the standards established for the evolutionary ALWR would utilize a conventionally configured reactor coolant system, but with substantially improved reactor coolant pump seal design, steam generators having greater secondary side-water inventory, and a pressurizer designed to accommodate a full post-scram pressure and temperature transient without requiring pilot-operated relief valve actuation. The BWR version of the evolutionary ALWR would employ internal recirculation pumps and improved control rod drive design. Work has also begun at EPRI on developing utility requirements for the more passive ALWR mid-size plant designs described below.

Large Plant Certification

This task of the ALWR program includes support for demonstration of the improved licensing process needed for all advanced reactors by certification by the NRC of one or more large (1,250 to 1,350 MWe) standard plant designs. Reactors being reviewed by the NRC include the General Electric (GE) advanced boiling water reactor design, developed in collaboration with the Japanese, and the Combustion Engineering (CE) "System 80+" advanced pressurized water reactor design.

The GE ABWR incorporates significant improvements and simplifications to enhance safety and operating reliability. For example, the use of internal recirculation pumps eliminates the recirculation piping external to the reactor and provides increased access and reduced radiation exposure for maintenance in this area. The new, fine-motion control rod drive mechanisms, the improved containment and reactor building design, three independent Emergency Core Cooling divisions, and use of digital/solid state control are additional examples of features where reliability has been improved, and at the same time, the overall design has been simplified and provided with increased operating margin and flexibility. The vulnerability to core melt accidents has also been reduced by a factor of ten compared to the average of current plants.

General Electric has submitted its Standard Safety Analysis Report to NRC. Assuming favorable review results, we anticipate Final Design Approval in 1990, and Design Certification in 1991. In parallel with these activities, the design also is being licensed in Japan, where two units already have been ordered. A 4-year construction schedule has been established which is significantly better than recently completed U.S. plants.

The CE System 80+ design is based on the current System 80 design that already has a Final Design Approval from NRC. Using System 80 as a starting point, the System 80+ incorporates modifications to conform to the ALWR Utility Requirements Document and the NRC severe accident policy. As a result, System 80+ will include significant design improvements to enhance safety and overall plant performance, simplify the design, and reduce cost. Improvements which increase the operating margin, such as increased core operating margin, larger pressurizer volume, increased steam generator secondary volume and improved steam generator tube material are included.

As of mid-1989, CE had submitted about 50 percent of its safety analysis reports to the NRC. The CE submittals and NRC review have been on a roughly parallel schedule to that for the GE ABWR. However, the scheduled certification date of 1991 has been delayed because of a decision by NRC to require applicants for standardized plants to include the Balance of Plant in their safety review.

Mid-size Passive Plant Program

In this task area, design, development, and certification activities are being supported for mid-size (600 MWe) plant concepts incorporating more passive safety features. These plants offer the opportunity to incorporate further, highly desirable changes to light water reactors.

Designs are being developed which will not only build on the extensive experience base from the last three decades of light water reactor operation, but will also take advantage of potential simplifications and innovations in design and construction that are unique to the lower power rating.

The incentives for developing this advanced design plant concept are substantial:

- The passive plant protection systems envisioned are much simpler in concept than the complex safety systems utilized in existing plants. Therefore, the passive plant offers far greater opportunity than the evolutionary plant to effect wholesale simplification (in the form of reduction of many valves, pumps, takes, instruments, etc.) with attendant improvement in construction cost and schedule, plant operability, and maintainability.

- By eliminating reliance on active components and human intervention, the mid-size plant has the potential to offer greater safety under a wider range of upset conditions and internal and external plant threats such as loss of all electrical power.

- This design may be more easily licensable than existing plants because of the simple straightforwardness of safety-related equipment.

- The lower power rating may more closely match the load-growth requirements of many utilities.

Recognizing these potential benefits, a program was initiated in 1986 for the conceptual design development and key features testing of two 600 MWe plant designs - the GE simplified boiling water reactor plant, and the Westinghouse AP600 pressurized water reactor plant. The work accomplished to date has clearly demonstrated the advantages of these concepts, and the desirability of proceeding with certification of standardized mid-size plants designs.

The GE simplified boiling water reactor design features a natural circulation reactor. A gravity driven core cooling system, working in combination with an elevated pressure suppression pool and reactor depressurization valves, provides abundant cooling of the reactor, basically by passive means, in the event of a large loss-of-coolant accident. The isolation condenser facilitates reactor decay heat removal by natural circulation without use of the feed or steam systems. A passive steam injector system provides high pressure feed to the reactor to back up the normal feedwater system. Verification testing of these key features is in progress. Plant arrangement and construction studies have also been performed to simplify and improve the constructibility of the plant.

The AP600 design employs significant simplifications and innovations in design, construction, and operation facilitated by the lower power rating. This concept features the application of canned motor reactor coolant pumps to improve reliability and maintainability, elimination of reactor vessel bottom head penetrations, a passive containment heat removal system, and extensive use of prefabrication and modularization to improve constructibility.

The AP600 design has proceeded to the point where a detailed cost estimate and construction schedule have been made. The results show a cost, based on the detailed construction plan, of $1270/kilowatt for "overnight" construction, and a construction schedule of 36 months. These results compare very favorably to cost estimates of other advanced coal and nuclear plant systems.

We are now proceeding with the next phase of the mid-size plant development program--the detailed design and certification for these plants. A Request for Proposals for this phase of the program was issued in January 1989 and proposals were received in early May. Work was initiated under the Westinghouse and General Electric contracts resulting from this solicitation in February and April 1990, respectively.

The federal government cost-share for this phase will be limited to 50 percent or $50 million, whichever is the lower, for each plant design supported. For continued development of a pressurized water reactor and boiling water reactor, the total additional Government cost for the mid-size passive plant program is expected to be $20 million/year over approximately a 5-year period. The coordinated DOE/industry program on these mid-sized plants should result in availability of certified mid-size plant designs by 1995.

SUPPORTING PROGRAMS

Of direct benefit to both the large and mid-size plant activities, Duke Power Company and Stone & Webster Engineering Company have been performing studies to improve plant construction. Drawing on the experience of utilities, reactor suppliers, architect-engineers, and constructors, these studies have investigated all important aspects of construction--such as construction technology, management, and design for construction--to develop a compendium of good construction and design practices that should significantly improve construction quality, duration, and cost.

The Department, through its Idaho National Engineering Laboratory, has been supporting both the Utility Requirements Document activity and the Certification programs in the area of severe accidents. This has included recommendations on design approaches to eliminate or reduce severe accident vulnerabilities as well as the development of improvements in analysis tools to allow more realistic assessments of these designs for postulated severe accidents. This severe accident activity also provides support to ALWR program participants in their interactions with NRC.

Finally, the 100-plus light water reactor powerplants now in commercial operation in the United States are a large untapped resource of future energy when one considers that their current license life of 40 years is not based on technical restrictions. An additional 20 years of operating life, representing nearly 96,000 megawatts of capacity, is potentially available and can directly offset some of the need for new or replacement generating units. In order to preserve this resource, the criteria and technical bases for replacement, refurbishment, or continued use of components and systems, are needed by both utilities and regulators. In addition, the procedural requirements to be used by regulators for license extension reviews must be developed and agreed upon. This ranges from questions on compliance with regulations issued during the plant operating life to issues on cost recovery allowances by economic regulators.

Support for two lead plants, the Yankee Rowe plant and the Monticello plant, was initiated in early 1989. This cost-shared effort involves preparation of safety analyses and applications for license renewal. The plan is to submit the lead plant applications to NRC in 1991, with the objective of obtaining renewals of their licenses by 1993. This accomplishment will pave the way for other operating U.S. nuclear plants to receive renewal licenses in the 1990's.

CONCLUSION

The coordinated national light water reactor program represents a vital element for restoring a viable nuclear energy option to the United States. The ALWR offers a high confidence opportunity for helping meet projected electricity requirements. While incorporating innovative means to increase safety, reliability, and operability, it is based on modest extensions of proven technology and on three decades of experience in LWR design, construction, and operation. The experience to date indicates that the potential of this program will be realized and that improved LWRs will be available for the 1990's and beyond.