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Consideration of safety level when a country selects nuclear power plant technology

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1. Introduction

Energy is essential for national development. Nearly every aspect of development requires reliable access to modern energy resources. States may have different reasons for considering starting a nuclear power project to achieve their national energy needs, such as lack of available indigenous energy resources, the desire to reduce dependence upon imported energy, the need to increase the diversity of energy resources and/or mitigation of carbon emission increases.

The start of a nuclear power plant project involves several complex and interrelated activities with long duration, typically lasting about 10 to 15 years. The main focus, however, is to ensure that the project is implemented successfully from the views of commercial benefits and, more importantly to ensure the acceptability of the public over long-term period, safety level achieved or to be achieved by the project.

This paper is aimed at providing consideration on the practical selection of a first nuclear power project in a country to ensure that the project will have enough safety level.

2. Consideration of Reactor Designs

2.1. Development of reactor designs

As is suggested by the Generation IV International Forum [1], reactor designs may be divided into four generations. The first generation consisted of the early prototype reactors of the 1950s and 60s. The second generation is largely made up of the commercial NPPs built since the 1970s which are still operating today. The Generation III reactors were developed in the 1990s and include a number of evolutionary designs that offer improved safety and economics.

Beyond 2030, it is anticipated that new reactor designs will address key issues such as closing the fuel cycle or enhanced proliferation resistance at the same time as competitive economics, safety and performance. This generation of designs, Generation IV, consists of innovative concepts where substantial R&D is still needed.

Depending on the number of modifications implemented, advanced reactor designs can be divided into ‘evolutionary’ and ‘innovative’. An evolutionary design is an advanced design that achieves improvements over existing designs through small to moderate modifications, with a strong emphasis on maintaining the essentials of the proven design to minimize technological and investment risks.

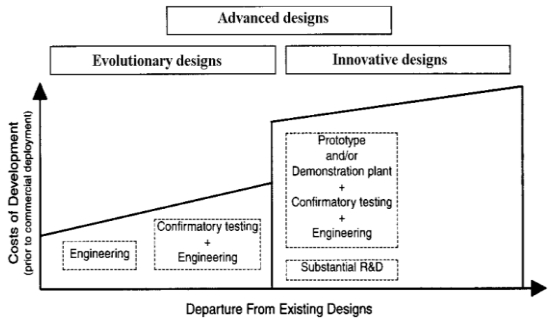

Figure 1. Implication of Costs in Advanced Reactor Design

As shown in the Figure 1, the development of an evolutionary design requires, at most, engineering and confirmatory testing. An innovative design is an advanced design which incorporates radical conceptual changes in design approaches or system configuration in comparison with existing practice. Substantial research and development (R&D) efforts, feasibility tests, and a prototype and/or demonstration plant are probably required prior to the commercial deployment of this type of design.

It is natural that more advanced design entails not only more costs and efforts but also uncertainty of its success in deployment. Thus, balanced decision should be made between future desirable features and current situation of both time urgency for energy and financial capability. It is more relevant to the country of first introducing nuclear power than countries running it since the latter would have affordable time and financial capacity benefited from nuclear power in operation.

2.2 Trends in evolutionary reactor designs

The following trends in the design of evolutionary reactors can be observed.

Firstly, there is a trend towards reducing the overall capital cost of a new NPP by reducing and simplifying plant systems and components; developing standardized designs that need to be validated and licensed only once; using advanced construction technologies and management practices that shorten the construction schedule and improve the quality or by incorporating modularity in the design, which enables factory pre-fabrication of both structural and system modules.

The second trend is towards lowering operating costs through the optimization of the fuel cycle. Savings result from increased plant availability, more effective use of fissionable resources and minimization of waste and spent fuel quantities and management costs.

The third trend is towards improved performance, by various means, including the use of smart components that monitor their own performance and warn operators about incipient failures; in-service testing and maintenance; relying on probabilistic risk assessment methods and databases that allow designers to focus design efforts on the systems and components with higher risk of failure; or using digital instrumentation and control (I&C), as well as improved human–machine interfaces that significantly reduce human errors.

Lastly, many evolutionary designs have been developed based on 'user requirements', that is, the lessons learned from the operation of the existing fleet of NPPs.

2.3 Descriptions of evolutionary designs being considered for construction in Vietnam [2]

The WWER-1000 is a Russian pressurized WCR that incorporates active and passive safety systems and has been adapted to Western standards based on the substantial design and operating experience accumulated in the Russian Federation over the last 50 years. The WWER-1200 is a scaled up version of the WWER-1000. Like its predecessor, it is a four-loop design with horizontal steam generators which have a track record of providing the longest operating life. The WWER-1200 also includes active and passive safety systems, double containment and severe accident mitigation systems, such as a core catcher.

The advanced pressurized water reactor (APWR) is a four-loop PWR developed jointly by a group of Japanese utilities, Mitsubishi Heavy Industries (MHI) and Westinghouse that relies on a combination of active and passive safety systems. The high capacity APWR, with 1500 MW (e) (1700 MW (e) in Europe and the US), takes advantage of economies of scale and uses high performance steam generators.

The advanced power reactor 1400 (APR1400), with a rated power of 1400 MW (e), is the largest two-loop PWR currently available. It was developed in the Republic of Korea, based on accumulated experience from the design and operation of OPR1000. The APR1400 incorporates a number of changes in response to operators' needs for enhanced safety, performance and economics and to address new licensing requirements such as the mitigation of severe accidents.

3. Discussions

How people view risks and judge value of safety level is perhaps the most challenging factor for a country to take into account when determining the introduction of nuclear power technology – not least because these views and value judgments are not static but change according to circumstances. Such non-static features are linked in part to:

- the rapid rise in information technology which nowadays plays an important role in shaping opinions by making it easier for people to have information on the risks that may affect them and the society in which they live;
- the increased pace in exploiting advances in scientific and technological knowledge, which has led to an increased focus on continuous improvements in safety which would be implemented by the operator and/or imposed by the regulator;
- The greater affluence in society, as typically emerges in western countries where the majority of people in no longer have to struggle at subsistence level. As a consequence, the acceptance of industrial activity to gain increased standards of living is no longer as readily given as when the fight against hunger and poverty overshadowed everything else.

What is acceptable level of safety is a matter for society to decide by weighing the risks and benefits of any particular activity and judging where the balance lies. Clearly this balance is different for different countries and varies with time in any individual country. The challenge to any regulatory body is to interpret society's answer to the question "how safe is safe enough?" and to reflect it in the regulatory standards and enforcement strategy that it adopts. [3]

In reality, however, it is extremely difficult for any regulatory body to make an accurate assessment of the level of risk that is deemed to be acceptable by the society. Some possible indications obtained from such as parliamentary resolution and media coverage with public opinion are susceptible to subjectivity and the information comes too late to guide the normal regulatory decision that is required for selecting nuclear power technology.

4. Conclusions

As seen in the previous sections of this document, various technology options for near- and mid-term use are available to countries considering starting a new nuclear power programme and every nuclear reactor design has its own key characteristics and benefits. The selection of the most suitable design requires a comprehensive assessment of (1) the technical and economic benefits of each design, (2) the safety level achieved by the design, (3) and the acceptability of the safety level by the society, all of which must be evaluated against the conditions and the needs of each country.

With these considerations, Vietnam can select a suitable design in the future. Specially, on import aspect, Vietnam can have a nuclear power plant design that meets the demand with enough safety level and low investment cost. Considering the timespan covered by a nuclear power plant, the proper approach would be the inclusion in the selection criteria of the extent of which each design could be improved in safety whenever the requirement from society varies and/or new scientific advances find rooms for improvements.

REFERENCES

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