Role of Expert Evaluation System for Deploying Advanced NPPs in China

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Abstract: Sustainable development of Chinese economy in 21st century will heavily rely on sustainable and clean energy supply. According to current structure of energy resources and environmental stress of energy consumptions, nuclear power will be an indispensable choice for generating electricity in China. It is foreseeable that China will build a significant number of advanced nuclear power plants (NPPs) in near future. To select a suitable type of NPP from various advanced commercial designs should rely on objective and justified assessments according to the most realistic possibilities available to potential utility owners. Many aspects, such as economic competitiveness, reactor safety, sustainability of energy resources, etc., must be taken into account. The expert evaluation system based on modern database technology and information managing techniques will be a very useful tool for the utility owner and/or the authorized government institutions to make decision. This paper illustrates a general description for establishing an expert evaluation system for deploying advanced NPPs in China and the main index system to assess or discriminate the characteristics of possible design options. The vital role of developing such an expert evaluation system is addressed.

KEYWORDS: advanced reactors, expert evaluation system, Chinese NPPs

I. Introduction

To realize harmonic and sustainable development between man and nature is the up-most ambition of human being. The culture embedded in more than 3000 years brilliant civilization of China has always been reflecting the thoughts of “harmonic entity of man and nature” from numerous great ideologists, politicians and scientists. The modern industrial technology based on western scientific civilization is also pursuing the philosophy of sustainable development. The environmental and ecological issues have been paid much more attention to with the human civilization goes towards future. Nowadays, more than 400 nuclear power units is producing safely and reliably about 17% of total electricity used by human being without emission of greenhouse gaseous CO₂. This is the glorious achievement made by nuclear energy technology which originated from the middle of 20th century and experienced quite a vicissitudinous history of development.

Although many challenges from economic aspects, safety, radioactive waste disposal and barriers for non-proliferation considerations have resulted in a valley in the schedule projecting nuclear power plants under construction worldwide, nuclear energy so far is still an alternative option to substitute oils and natural gas in large scale for generating electricity in predictable near future. According to the forecast of the energy market processed by authorized institutions, the potential market for nuclear power plants in China is in the scale of 240GWe. Currently the total capacity of nuclear power plants (NPPs) including the units under construction is only slightly over 8GWe. Furthermore, the market oriented economical reform and regaining WTO membership of China will certainly make utilities possess more freedom to draw future development plan and to finance huge investment for new NPP projects. It will be foreseeable that the potential Chinese market for new units of NPPs is very attractive to both international and domestic vendors and equipment suppliers.

Past experience of China in developing its nuclear power industry has shown that the endless debate regarding the selection of technical roadmap among experts of Chinese nuclear industry may delay, diminish or even definitely close the opportunities for finalizing more deals of nuclear generation units. Therefore, to establish an objective expert evaluation system with the collective wisdom of relevant experts from nuclear industry, regulatory body, government committee for economic development planning, energy strategists, financial sectors, and scientific research and management consortiums will be of great importance.

II.Indices and Criteria

To establish a creditable expert evaluation system, the design of the evaluation scope and the selection of the indices and the corresponding evaluation criteria will play a significant role. This section discusses the evaluation criteria for establishing the expert evaluation system, which are going to be processed from the responses of selected Chinese experts to the survey sheet of Request for Information (RFI) designated by a research group led by China Guangdong Nuclear Power Holding Co., LTD. All items in this RFI
survey sheet are carefully prepared. The main references
guiding the selection of the evaluation scope and the criteria
are the reactor evaluation criteria for the Generation-IV2)
program and the Near Term Deployment Roadmap3) program
initiated by US department of energy. However, some
practical situations in China have been taken into account.
The key considerations related to Chinese characteristics in
the RFI survey sheet prepared by the present study include the
approval procedure for granting a new NPP project by
Chinese government, the licensing process for certifying a
selected type of nuclear reactor and the finance practice in
China.

The evaluation scope has primarily defined by following
indices, namely:
- Economic competitiveness
- Safety and reliability
- National energy policy
- Untroubledness
- Sustainability
- Technical characteristics
- Industrial Infrastructure

Under each of these top-level indices, a number of items
have been chosen as criteria items to objectively qualify the
designs for any specified nuclear power plant proposed by
future international or domestic bidders. These criteria items
are listed below in accordance with the relevant indices.

(1) Economic competitiveness
- Capital investment
- Construction flexibility
- Adaptability to electric market change
- Competitiveness to alternative energy resources
- Operation reliability and robustness
- Backend and decommission cost
- Demand of electric market

(2) Safety and reliability
- Consistency to existing safety regulations and laws
- Safety characteristics of facilities and components

(3) National energy policy
- Consistency to the guidelines of national energy policy

(4) Untroubledness
- Capability to resist proliferation
- Capability to resist terrorist attack and abrupt event
- Quantity of radioactive waste and ultimate disposal

(5) Sustainability
- Sustainability of fuel supply
- Environment sustainability

(6) Technical characteristics
- Mature technology
- Advanced technology
- Trend of technology development

(7) Industrial Infrastructure
- Capabilities to design, manufacture and construct
  proposed nuclear power plants
- Consistency to fuel supply industry/system
- Consistency to national fuel cycle industry/system

Figure 1 schematically shows the structure of the
evaluation indices-criteria system mentioned above. The
importance of each index and criteria will be quantified either
with a waiting factor or with both a waiting factor and a score
to be obtained from the survey results of the responses of the
selected experts to the survey sheet of Request for
Information (RFI). This method is somehow every similar to
that reported by near term deployment group (NTDG) of the
United States for Near Term Deployment Roadmap3) program.

The survey has been prepared and will be conducted soon
among Chinese experts. The data collection and treatment are
still underway. Approximately, in the middle of next year all
input data will be ready.

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Fig.1 index-criteria structure

plants will involve many aspects. The considerations for
making final decisions must be conscientiously weighted
among wide spectra of influential factors. Therefore, to
establish a set of evaluation index system with multiple-layer
structure which can correctly represent current situation and
future requirement is the corner stone for the design and configure an expert system suitable for the assessment of various advance nuclear power plant designs.

The index-criteria system is a quantified system reflecting the intrinsic relation among relevant factors and the importance of each item. The principles to establish the index-criteria system include:

(1) Comprehensive coverage: the index-criteria system should reflect comprehensive real situation of various reactor types without major missing items;

(2) Scientific simplicity: The evaluation index-criteria system should be scientific. The total size of relevant items should be appropriate. If the size is too large, the number of layers is over-expanded and the indices are too dedicated to details, the user’s attention will be attracted to sophisticated details while major important items would be neglected. However, if the size is not large enough, the number of relevant layers is not well-expanded and the indices are too coarse, the evaluation system may result in misleading and the real features of various advance nuclear power plants may not be sufficiently addressed.

(3) Independence: the indices and the relevant criteria should be independent each other.

(4) Stable comparability: the evaluation indices and their corresponding criteria items should possess clear contents which can be measured with either weighting factors or other quantified means and easily used to compare different types of nuclear power plants.

(5) Flexible and easy to manipulate: The evaluation index-criteria system should be easy to manipulate and should be of sufficient flexibility so that the decision maker can flexibly apply the system according to the actual situation which may change with time.

III. Database and the Evaluation System

The requirements of the expert system for evaluating or assessing the designs of various types of nuclear power plants should include following items:

(1) Based on existing input data from the expert responses of the designated survey, the expert evaluation system should possess capabilities to select evaluation models, to simulate and calculate with the selected models and to analyze the calculation results, as well as to provide necessary explanations to the evaluation results.

(2) The technology for establishing an expert system with which knowledge is expressed and processed should be combined with modern database technology, so that the evaluation system will become an knowledge processing oriented solver for the evaluation problems. Meanwhile, this system will be able to share information for all relevant problems.

(3) The database under development should encompass not only the data managing-deducing functions of classical database, but also can provide well specified information database with good performance to the expert evaluation system.

(4) The database should be easy to expand and to manipulate, including to add, to delete and to modify items of expert knowledge. The configuration of the database should be clearly specified for the purpose of easy maintenance.

(5) The operation of the database should be consistent to the WINDOWS-2000 or WINDOW-XP operation, user friendly and interactive man-machine interface (MMI). The stored data should be mutually independent or separated.

The evaluation system has applied database tools, either Microsoft SQL SERVER or ORACLE. The design of the database is configured with classical data connection model. The main procedures for the database design include:

a) Demand analysis: to investigate and analyze the user requirements

b) Conceptual design of the configuration: this conceptual design is the key for the entire design of the database. By summarizing, inducing and abstracting the user requirements, a conceptual model independent of the actual database management system then is formed.

c) Logic structure design: logic structure design intends to convert any typical conceptual configuration design to a data model supported by a database management system, and to optimize the formed data model.

d) Physical structure design: it selects the physical structure which is the most appropriate to the application software environment for the logic data model. This part should be automatically managed by the database management system.

e) Construct the database: the database designer or developer applies the data processing language and host language provided by the database management system to construct database, to program and test the applying codes, to organize input data for the database system and to execute the testing operation in
accordance with the results of the corresponding logic and physical designs.

f) Operation and maintenance: the application system of the database can formally be put into operations after preliminary testing. The database system must continuously be assessed, adjusted and modified during formal operation stage.

The database system developer should collect sufficient information available as the ground knowledge of the expert evaluation system. The collected information regarding all types advanced nuclear reactors should be added into the database continuously during the operation from time to time whenever available. The continuous update of the index-criteria system and the information reflecting the state-of-the-art of various types of nuclear reactors will keep the evaluation system be always applicable with the changing situations.

The E-R (Entity-Relationship) diagram of the expert evaluate system is depicted as Fig. 2. The data describing model for the expert evaluation system and the relevant database is based on this E-R diagram. In this diagram, the rectangle frame represents the relationship entity, the ellipse frame displays the property of either the entity or the relationship and the diamond frame delineates the connection among the entities.

The expert evaluation system should also be designed in such a way that the user can easily search and document the stored information in the database. The design structure of the evaluation system is depicted as Fig. 3. The comparable items for evaluating different types of nuclear reactors can be quantitatively weighted with respect to specified evaluation criteria. Thus, the evaluation system can be used to supply quantified ranking of the selected reactor types according to the specified criteria.

IV. Discussions and Remarks

In the previous sections, the motivation to develop an objective expert evaluation system for selecting advanced nuclear power plant for near future requirement (about 2010 to 2015). The design of this system has considered its possibility open to medium or long term needs. Therefore, the evaluation indices and the corresponding evaluation criteria include a wide range of items to fulfill the requirements for both near and long terms.

The general summarization of the index-criteria system has been illustrated. The design principles and a comprehensive entity-relationship diagram for establish the expert evaluation system has been given. The evaluation objects may cover a variety design categories of advanced NPPs, such as advanced light water reactors (ALWR), high temperature gas cooled reactors (HTGR), advanced CANDU reactor (ACR), and various types of fast reactors. Although the intention of the expert evaluation system is aimed at mature designs for commercial deployment, some conceptual designs with future perspective have also been taken into account. The information about these conceptual designs is going to be collected as much as possible in the database. The completion of the sufficient information will be accomplished later whenever the corresponding technologies become mature enough for commercial deployment.

As described in section I, the potential Chinese market to build new nuclear power plants in future is quite optimistic. Because the initial capital cost per kWh electric generation capacity for any type of nuclear unit is still much higher than fossil fuel power plants, especially much higher than coal-firing power plant in China, the number of new nuclear power plants will still be limited at low development level in near term. The acceleration of the current momentum will mainly depend on the variations of following factors:

- National energy policy
- Environmental stress
- Market reform in financing new projects
- Market reform of electric power industry

Therefore, to plot the best roadmap for deploying advanced nuclear power plants in China and to select the most appropriate type of advanced NPPs in order to compete with alternative energy resources is very important for creating good imagine of nuclear power in Chinese market. The good imagine of nuclear power at its initial development stage will be badly needed for accumulating experience and money to roll up entire nuclear power industry. The expert evaluation system based on collective wisdom of experts throughout the whole China or even from international cooperation certainly will be very useful for accelerating the development of Chinese nuclear power industry.

Moreover, the evaluation results from the objective expert evaluation system will play significant role to help authorities make final decision of granting approval to the most suitable type of advanced nuclear reactors for future NPP projects.

References


**Fig. 2** Entity-Relationship Diagram of the Expert Evaluation System for Advanced NPPs

**Fig. 3** Structural Diagram of the Expert Evaluation System