Available online at www.sciencedirect.com

ScienceDirect

Nuclear Energy and Technology 3 (2017) 158–163

www.elsevier.com/locate/nucet

Consideration of economic risks in a comparative analysis of nuclear technologies with different maturity levels

A.A. Andrianov[a,*], Yu.A. Korovin[a], I.S. Kuptsov[a], V.M. Murogov[a], O.N. Andrianova[b]

[a] *NRNU "MEPhI", 31 Kashirskoye shosse, Moscow 115409, Russia*

[b] *JSC "SSC RF—Institute for Physics and Power Engineering named after A.I. Leypunsky" (IPPE), 1 Bondarenko Sq., Obninsk, Kaluga Region 249033, Russia*

Available online 30 May 2017

Abstract

Less developed reactor technologies are characterized by a high uncertainty level of the key performance indicators, as compared to more mature options, due to lack of information on the design, operation and cost data, etc., while the expected performance of such systems is normally more attractive in comparison with more mature options. Evidently, a greater uncertainty leads to higher economic risks involved in the deployment of the respective technology. Evaluating comparatively the competitiveness and performance of reactor technologies at different maturity levels requires taking into account economic risks to balance the judgments regarding the expected performance of the considered options. A reliable basis for this is formed by the economic risk theory.

Evaluation of risk indicators requires calculation of characteristics for probabilistic distributions of economic performance indicators and systemic use of statistical approaches based on Monte Carlo methods. Demonstration analysis results for the risk indicator evaluation have been discussed as applied to different economic performance indicators based on the example of a comparative analysis for two hypothetical light water reactor technologies to be considered in the selection of the most attractive option. Use of economic risk indicators for the comparative evaluation of reactor technologies appears to be helpful to decision makers not familiar with the technical characteristics and performance measures of reactor technologies but informed about the economic risk concepts. Such methodology may be employed efficiently to interpret the ranking results in a multi-criteria comparative evaluation of less and more mature reactor technologies.

Keywords: Reactor technologies; Performance indicators; Economic risks; Uncertainty; Decision-making.

Introduction

Less developed reactor technologies are characterized by a high uncertainty level of the key economic performance indicators, as compared to more mature options, due to lack of detailed information on the peculiarities of the design, operation and cost data, etc. However, the expected performance of such technologies normally seems to be more attractive than in the case of more mature options, while a greater uncertainty leads to higher economic risks involved in the deployment of the corresponding technology.

Evaluating comparatively the competitiveness and performance of reactor technologies at different maturity levels requires consideration of economic risks for balancing the judgments regarding the expected economics performance of the options in question. The economic risk theory forms a reliable basis for judgments on potential costs, benefits and risks in a comparison of less and more mature reactor technologies for informing decision makers responsible for issues involved in the deployment of new technologies, where a distinct understanding of associated risks is required.

* Corresponding author.

E-mail addresses: andreyandrianov@yandex.ru (A.A. Andrianov), korovinyu@mail.ru (Yu.A. Korovin), kuptsov_ilia@list.ru (I.S. Kuptsov), victor_murogov@mail.ru (V.M. Murogov), oandrianova@ippe.ru (O.N. Andrianova).

Peer-review under responsibility of National Research Nuclear University MEPhI (Moscow Engineering Physics Institute).

Russian text published: Izvestiya vuzov. Yadernaya Energetika (ISSN 0204-3327), 2016, n.4, pp. 156–163.

http://dx.doi.org/10.1016/j.nucet.2017.05.012

It should be noted that, despite the significance of issues concerned with the assessment of economic risks involved in the design, operation and decommissioning of nuclear technologies and related facilities as part of major international methodological efforts aimed at the assessment and comparative analysis of nuclear energy systems and their components, such issues have not been properly addressed [1–5]. Meanwhile, consideration of respective aspects may change one's view of the compared options. Thus, for example, one of the arguments in favor of small and medium sized reactors is that the deployment of nuclear energy systems on their basis allows reducing the risks of the losing investments [6]. Consistent assessment of economic risks involved in the deployment of new reactor technologies may lead to a conclusion that uncertainties need to be reduced (including through additional R&D) before these technologies start to be implemented [7].

Evaluation of risk indicators (such as value at risk, expected shortfall, tail value at risk and others) requires calculation of characteristics for probabilistic distributions of economic performance indicators (net present value, present value, internal rate of return, discounted payback period, levelized cost and others) and systemic use of statistical approaches based on Monte Carlo methods. The paper uses an example of a comparative analysis for two hypothetical light water reactor technologies (less and more mature options) to present the results of a demonstration analysis for evaluating economic risk indicators to demonstrate the applicability of economic risk concepts for the comparative analysis of nuclear technologies and the contradictions between economic performance and risk indicators to be taken into account in consideration of issues involved in the selection of the most attractive reactor technology option to deploy [8–10].

Comparison of alternatives in conditions of risk and uncertainty

The assessment of the power project economic performance in conditions of liberalized energy markets, where entities seeking the maximization of profit in a new surroundings are given freedom of decision making, relies heavily on the principles and criteria other than having been used in a centralized economy where the criterion of the minimum total socially necessary costs was the key criterion of effectiveness [11,12]. Here, the base theory of the effective project selection is the theory of cash flows which uses such key criteria of economic performance as net present value, present value, internal rate of return, payback period and some others (Table 1) [13,14].

These indicators serve as the basis for the multi-criteria comparative evaluation of the economic performance and competitiveness of projects for deployment of power systems and their components. Depending on the task in hand, a particular set of performance indicators is used. For instance, net present value (*NPV*) depending on the electricity rate is the base indicator in the event of orientation towards the external investor. In the event of orientation towards the owner, integral present values (*PV*) are normally taken as the base indicators in the NPP project economic performance assessment. In a general case, the entire spectrum of performance indicators reflecting different project aspects shall be taken into account.

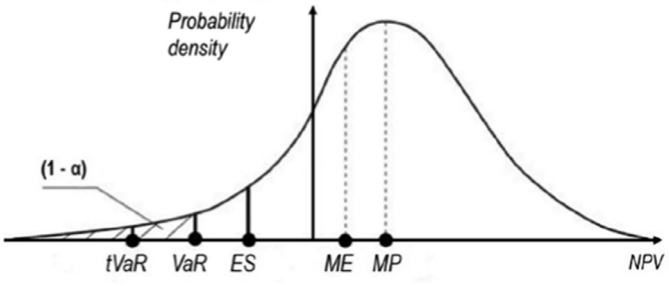

Fig. 1. Relative positions of risk evaluations based on different indicators.

Since risk is a probabilistic category, which is explained by the uncertainty of the knowledge of the future, probabilistic methods are broadly used to evaluate risk indicators. Uncertain parameters of the conditions, in which the project is implemented, and the project performance define the resultant uncertainty in the values of the above economic performance indicators, for each of which it is possible to evaluate statistical risk indicators. The criteria one may use to support the decision-making in risk conditions are characterized by alternatives and take into account the peculiarities of corresponding statistical distributions, this defining the application range of criteria. Listed below are the most commonly used criteria (risk indicators) for the comparison of alternatives in a situation of risk and uncertainty [15,16].

- Expected value (*ME*), the criterion based on which options are evaluated by the mathematical expectation value (this indicator may be considered as an economic performance measure).
- Most probable value (*MP*), the criterion in accordance with which the evaluation result is the option having the greatest probability (this indicator may be considered as another economic performance measure).
- Value at Risk (*VaR*) is the monetary valuation of loss which will not exceed the expected loss with the given probability equaling the confidence level α. Consequently, the loss in $1 - \alpha$ cases will make a quantity greater than *VaR*. Therefore, one may state with the probability α that the loss will not exceed *VaR* units.
- Expected Shortfall (*ES*) evaluates the distribution tail intercepted by the given boundary and represents the mathematical expectation of the distribution tail characterizing the loss.
- Tail Value at Risk (*tVaR*) is used to evaluate capital insufficiency risks and is equal to *ES* for which *VaR* has been taken as the boundary.

Fig. 1 presents the positions of different risk criteria based on the example of the *NPV* indicator probability distribution (negative indicator values are the losses, and positive indicator