Study on Risk Assessment of Inland Nuclear Power Investment Construction Projects by Kazakhstan

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Abstract. This article is the first attempt to conduct a comprehensive evaluation of Kazakhstan's inland nuclear power investment construction projects. Based on the summary of existing research results of scholars at home and abroad, a systematic analysis of the sustainable development model is made from the following four aspects to conduct safety evaluation research on domestic nuclear power construction in Kazakhstan: 1) Probabilistic safety evaluation for Kazakhstan's inland nuclear power construction; 2) Public perceived risk evaluation for nuclear power construction in Kazakhstan; 3) Economic evaluation for recirculating systems of spent fuel; 4) Benefit risk evaluation for Kazakhstan's inland nuclear power construction. Based on China's multi-criteria decision analysis of dynamic system modeling, we add noise to the uncertain factors of the safety evaluation of Kazakhstan nuclear power investment projects and then perform noise reduction to refine our evaluation results. First of all, due to the non-convex optimization of tensor decomposition, there is no guarantee that the factorization will be determined by optimization. In addition, tensor decomposition can converge to different local optimal values corresponding to different initial values of the two tensors. Therefore, if the initialization value is set correctly, the result will be approximately optimal compared to the case where the initial value is far from the global optimal value.

1. Introduction

Energy is the cornerstone of modern society, and electricity is the core of energy conversion and electrical age civilization. It is as large as affecting industrial development and as small as affecting people's normal life [1]. Developing electric energy is an important part of international economic cooperation. For example, in the area of China's "Belt and Road" initiative and Kazakhstan's "Belt and Road" strategy, to accelerate the construction of a community of human interests and destiny, China and Kazakhstan will cooperate to build an international energy base. The role of nuclear power as the cleanest energy can be brought into full play. China and Kazakhstan cooperate in the construction of two extra-large nuclear power plants in the Balkhash and Aktau regions of Kazakhstan to build this country into an indispensable regional international energy output center. The produced electricity is sent to Central Asian countries by AC and DC UHV transmission lines, to countries with severe shortages such as Afghanistan, Pakistan, India, and to the central and eastern regions of China, and to Russia, Mongolia, Azerbaijan, Turkey, Iran, Iraq, Saudi Arabia and some countries in Europe (Germany, Spain, Belgium, etc.) in order to solve the problem of power shortages in socioeconomic
development, to improve local people's production and living conditions, and benefit more than 3 billion people in the surrounding areas.

Table 1. The largest transmission line in Kazakhstan grid in 2018

| High voltage transmission and transformation line | Transmission capacity (Megawatt, МкВтч) |
|-------------------------------------------------|--------------------------------------|
| ВЛ № 5817 (Эк. ГРЭС-2 – Экибастузская 1150)      | 5175.6                                |
| ВЛ № 5117 (Эк. ГРЭС-1150 – Агадырь)              | 4788.0                                |
| ВЛ № 5120 (Эк. ГРЭС-1 – Нур)                    | 4068.7                                |
| ВЛ № 5138 (Нур – Агадырь)                        | 3339.1                                |
| ВЛ № 5019 (Таш. ГРЭС-1 – Шымкент)                | 3070.9                                |
| ВЛ № 5320 (Агадырь – ЮКГРЭС)                     | 2997.5                                |
| ВЛ № 5300 (Агадырь – ЮКГРЭС)                     | 2920.6                                |
| ВЛ № 5050 (Эк.ГРЭС-1 – ЦГПП)                     | 2154.5                                |
| ВЛ № 5537 (ЕЭК – Иртышская)                     | 2018.8                                |
| ВЛ № 5032 (БАЭС – Степная)                      | 286.1                                 |
| ВЛ № 2163 (Шу 220 – Главная)                     | 958.9                                 |
| ВЛ № 2103 (ПС 143 Робот – ТЭЦ 3)                 | 950.6                                 |
| ВЛ № 3050 (ЕЭК – ПС 51)                         | 786.8                                 |
| ВЛ № 2238 (Кар.ГРЭС-2 – Карамурун)               | 782.5                                 |
| ВЛ № 2173 (ПС 7 АХБК – ПС 140 Западная)          | 730.6                                 |
| ВЛ № 2419 (Таш.ГРЭС – Шымкент)                   | 722.5                                 |
| ВЛ № 2429 (Таш.ГРЭС – Жилга)                     | 707.8                                 |

Source: 2018 annual report of Harbin State Grid Corporation

2. Broad market prospects of nuclear power construction in Kazakhstan

The current installed capacity of power generation in Central Asian countries can no longer meet development needs. At the same time, the energy structure is obviously unreasonable. The replacement of old units is a heavy task and there is a lot of room for future adjustment. Countries in Central Asia have clear policies and plans to support power development. Kazakhstan and China have broad prospects for strengthening cooperation with other Central Asian countries in power development.

South Asia is the region with the most electricity shortages in the world. South Asia has a population of 1.744 billion, and the power development levels of countries in South Asia are generally backward. Power supply has always been an important factor restricting the economic development of South Asia [2-3].

3. Overview of nuclear power construction

The construction of a nuclear power base in Kazakhstan can provide clean energy to more than 3 billion people in the world, bring benefits, and make greater contributions to the construction of a community of human interests and of destiny. As nuclear power is a clean, safe, efficient, economical and high-energy-density energy source, considering that the development strategy of building Kazakhstan into a regional international energy base, considering that in the future, Kazakhstan's powerful power will be sent to China and Mongolia in the east, to four countries in Central Asia in the south, and to Afghanistan, Pakistan, India, Iran, and westward across the Caspian Sea to Azerbaijan, Turkey, Iraq, Saudi Arabia and other countries, to some European countries, and north to Russia, that will be a very grand nuclear power production base [4]. To build such a large nuclear power base requires international cooperation. Kazakhstan has advantages in state-owned energy and mineral resources, geographical environment, and location. China has capital advantages, technology and
equipment advantages, and rich experience in design, construction, and operation management. The complementary advantages of the two countries can provide clean energy to more than 3 billion people in the world, bring benefits, and make greater contributions to accelerating the construction of a community of human interests and destiny [5].

Although there have been many studies on nuclear power safety, it is rare to see nuclear power safety in Kazakhstan as a landlocked country in the Central Asia [6]. In this paper, the construction of an international production base for nuclear energy in a landlocked country like Kazakhstan is systematically studied from the perspective of its safety risks. The thesis focuses on the safety of nuclear power.

4. Characteristic of Risk Assessment and indicator metrics

From the perspective of the costs and benefits of nuclear power investment, risks and uncertainties of nuclear power investment are discussed. The factors to be considered in the nuclear power valuation include: environmental benefits of nuclear power investment (contribution to greenhouse gas reduction), the cost of radioactive nuclear waste disposal, and the risk of safety accidents in nuclear power operations [7]. The most important factors are the investment cost of nuclear power and the construction period of nuclear power.

We add noise to the uncertain factors in the evaluation of the benefits of nuclear power investment in Kazakhstan and then perform noise reduction to refine our assessment results. First of all, due to the non-convex optimization of tensor decomposition, there is no guarantee that the factorizations are all determined by optimization. In addition, tensor decomposition can converge to different local optimal values corresponding to different initial values of the two tensors. Therefore, if the initialization value is set correctly, the result will be approximately optimal compared to the case where the initial value is far from the global optimal value. An auto-encoder is a specific form of a neural network that consists of encoder and decoder components [8-9]. The encoder \( f() \) takes a given input \( v \) and maps it to a hidden representation \( f(u) \), while the decoder \( z() \) maps a reconstructed version of the hidden representation \( z(f(u)) \approx u \). Learning the parameters of the auto-encoder to minimize reconstruction errors is measured by some loss \( L(U, z(f(\tilde{u}))) \). However, the noise reduction auto-encoder slightly modified this setting to reconstruct the input \( u \) from the corrupted version with the motivation to evaluate a more efficient representation from the input.

Given the input \( U_c \) and \( U_y \) representing the feature sets of nuclear power remaining investment cost and benefits of nuclear power investment, the features of the remaining investment cost are represented by \( u_c = [z_{c_1}, z_{c_2}, \ldots, z_{c_i}, \ldots, z_{c_n}]^T \), and the features of nuclear power investment benefits are represented by \( u_y = [z_{y_1}, z_{y_2}, \ldots, z_{y_j}, \ldots, z_{y_m}]^T \). The noise reduction auto-encoder randomly destroys \( U_c \) and \( U_y \) to obtain \( \tilde{U}_c \) and \( \tilde{U}_y \). The characteristics of the remaining nuclear power investment cost and nuclear power investment benefit after destruction are expressed as: \( \tilde{u}_c = [z_{c_1}, z_{c_2}, \ldots, z_{c_i}, \ldots, z_{c_n}]_\tilde{}^T \), \( \tilde{u}_y = [z_{y_1}, z_{y_2}, \ldots, z_{y_j}, \ldots, z_{y_m}]_\tilde{}^T \).

In this paper, the evaluation of investment benefits mainly involves three parts: the initialization based on the evaluation model, the investment cost feature vector, and the calculated weight function.

For the latent feature preprocessing component, the complexity of the encoder input is mainly determined by the first layer, and the complexity of the update weights and biases is \( \phi(\omega \cdot d) \). The main computational cost of the investment cost feature vector is updating the objective function \( L' \) and the feature vector matrix. The time complexity of updating the objective function is \( \phi(\omega \cdot \omega_n \cdot d) \),
where $O_i$ and $O_n$ are respectively the number of positive samples and negative samples. At the same time, calculate the evaluation cost of a tuple $(c, g, y^e, t, y^p, w)$ is $\varphi(d)$. Since the number of non-zero terms is very small, the computational cost of the factor is linear relative to the number of samples. Therefore, the computational cost of updating the latent factors during the iteration $\varphi(O_i \cdot O_n \cdot d)$.

The cost of calculating the weight function is $\varphi(\rho^3 \cdot d)$, where the $\rho^3$ is corresponding number of the samples, and the time complexity is $\varphi(n^3)$.

5. Techniques and execution of framework

Then use four evaluation indicators to judge the feasibility of Kazakhstan’s inland nuclear power investment benefits, including precision, probabilistic safety assessment, accumulated gain of investment not abandoned, and mean average precision.

\[
\text{precision} @ t = \frac{|L_{t}^{\text{rec}} \cap L_{t}^{\text{tot}}|}{t}
\]

(1)

\[
\text{PSA} @ t = \frac{|L_{t}^{\text{rec}} \cap L_{t}^{\text{tot}}|}{L_{t}^{\text{tot}}}
\]

(2)

\[
\text{MAP} = \frac{\sum_{c} \text{AP}(t)}{|C|}
\]

(3)

\[
\text{AP}(t) = \frac{\sum_{t=1}^{L_{t}^{\text{rec}}} \text{precision} @ t \cdot \sigma(t)}{L_{t}^{\text{rec}}}
\]

(4)

\[
\text{AGINA} @ t = e^{-r(t_{i+1} - t)} \cdot Y^e (t_{i+1}) + Y^p (t)
\]

(5)

6. Sensitivity analysis

The weight utility function valuation model proposed in this paper evaluates the benefits of the third nuclear power technology investment in Kazakhstan. Considering the uncertainty of electricity prices, generation costs, investment costs, and nuclear power safety emergencies, we are using our model to evaluate this nuclear power investment project, and examining the impact of different factors on the valuation of nuclear power investment valuation. Therefore, the basic concept of large-scale nuclear power plants in Balkhash and Aktau was proposed. Considering the development strategy of Kazakhstan as a regional international energy base, Lake Balkhash is in southeast Kazakhstan and there are abundant water sources for large-scale nuclear power plants on its northern shore. The third generation + nuclear power technology AP1000 unit or CAP1400 nuclear power unit group can be planned here. It can be planned as a $12 \times 1000$MW unit. A group of $12 \times 1000$MW unit will be constructed in the near future, three groups of $12 \times 1000$MW units will be constructed in the medium term, and more than five $12 \times 1000$MW units in the long term.

Aktau is located on the Caspian Sea. The Soviet Union once operated a fast reactor power plant called the Aktau Nuclear Power Plant along the Caspian Sea. The plant closed in 1999 and has been in operation for a total of 27 years. It is mainly used for power generation and seawater desalination. It is also a good choice to build a large nuclear power plant here. It is also possible to use the third generation + nuclear power technology AP1000 unit or CAP1400 nuclear power group, which is planned as a $12 \times 1000$MW group. A group of $12 \times 1000$MW unit will be constructed in the near
future, three groups of $12 \times 1000$ MW units will be constructed in the medium term, and more than five
$12 \times 1000$ MW units in the long term. Electricity can be transmitted to Kazakhstan and Central Asian
countries through $1100$ KV AC respectively. The economic transmission distance of $\pm 1100$kV UHV
DC is in the range of 3000 to 5000 kilometers, the transmission capacity reaches 12000 MW, and the
transmission loss per thousand kilometers is reduced to 1.5%, and the DC transmission efficiency is
further improved.

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