Transactions of the Korean Nuclear Society Autumn Meeting
Changwon, Korea, October 30-31, 2025

Feasibility of Tailored SMRs for Data Center Baseload Requirements: Celebrating America's Third Nuclear Energy Supply to Data Center

Tae Ho Woo[1,*], Kyung Bae Jang[2], Chang Hyun Baek[1]
[1]*Department of Mechanical and Control Engineering, The Cyber University of Korea, Seoul 03051, Republic of Korea*
[2]*Department of Electrical Engineering, Gangneung-Wonju National University, Wonju 26403, Republic of Korea*
[*]*Corresponding author: thwoo@cuk.edu, thw_kor@hotmail.com*

Keywords : Data Center, Baseload, Nuclear Energy, Artificial Intelligence (AI)

1. Introduction

As the data size of information technology (IT) devices increases, the power supply strategy of data centers may change according to the 21st century environment. In particular, the use of artificial intelligence (AI) requires greater power demand, and as shown in Table 1, the power demand of data centers is expected to triple by 2030 [1]. Nuclear energy is attractive in terms of meeting these requirements, especially in terms of large supply capacity, high-quality electricity production, and carbon-free energy production.

Scalability of data center equipment, including cooling, power, and protection, which are hallmarks of data centers, is a key consideration for the future as we become more digital, and new data centers must be built with scalability in mind to accommodate the latest technologies [2,3]. In addition, data centers are set to account for 4% of global energy consumption and 1% of global greenhouse gas emissions by 2024, highlighting the climate impacts of data centers.

The most important features of building a data center using nuclear energy are large-scale power generation and zero carbon emissions, and based on this, Fig. 1 shows the characteristics of a nuclear data center [4]. The important thing here is that nuclear power plants (NPPs) are built to operate continuously, so they can stably supply baseload power. In 2024, Talen Energy sold its 960MW Cumulus Data Assets data center campus to Amazon Web Services (AWS), a subsidiary of Amazon and a cloud service provider [5]. Additionally, Constellation Energy signed a 20-year power purchase agreement (PPA) to power Microsoft data centers from Unit 1 of the Three Mile Island NPP [6]. Google is planning three 600 MW nuclear power projects for its data centers, and Elementl Power and Google have signed a strategic agreement to develop advanced nuclear power project sites. This marks the third nuclear-powered data center project in the United States [7].

2. Methods

Evaluating the energy supply of a data center requires analysis of many different variables and various uncertainties, so we present a data center operation algorithm for the variables of interest using system dynamics (SD), which is excellent for modeling through complexity techniques.

2.1. Meaning of Complex Algorithms

SD, a complex system method for evaluation based on various conditions, is a time-based feedback methodology that dynamically quantifies important data center issues. The flow structure of general events can be characterized by the level and rate of SD [8], which represents the accumulation of input data by integrating the designed model.

$$Stock\ (t) = \int_0^t [A(t) - B(t)]dt + Stock\ (0) \qquad (1)$$

Let $A(t)$ and $B(t)$ denote time-dependent variables representing conditions after and before an event, respectively. Stock(0) represents the initial quantity.

2.2. Modeling characteristics of nuclear data centers

In a data center using nuclear power, horizontal scalability means increasing the number of systems to increase processing capacity, while vertical scalability means responding by improving system performance [9]. Data center infrastructure efficiency (DCiE) is used as an indicator to evaluate the energy efficiency of a data center.

$$DCiE = \text{IT Equipment Power/Total Facility Power} \times 100\% \qquad (2)$$

The characteristic of data centers is that they operate 24 hours a day and always produce a base load of electricity [10]. Fig. 2 shows the base load and peak load [11].

$$Load\ Factor = \frac{Average\ Load}{Peak\ Load} \qquad (3)$$

Therefore, it means a system in which the base load is well reflected when the difference between the maximum load and the average load is small.

3. Results

SD simulation is performed to evaluate the possibility of successful operation of nuclear power in data centers. As shown in Figure 3, the trend is divided into the prosperity of data centers and the trend of nuclear energy in small modular reactors (SMRs). Here, Fig. 3(a) shows the relationship with a general data center, and Fig. 3(b) shows the relationship between the characteristics of the nuclear data center shown in Fig. 1 and nuclear power.

Each variable is expressed by four arithmetic operations, and the variable called INTEG represents the accumulated amount. In particular, DCiE is expressed in T5, and Load Factor is expressed in T6. Fig. 4 shows the results for load factor. Sequence1 is the base load power affected by nuclear power, and Sequence2 is the base load power not affected differently. As observed in the provided figure, no significant difference is noted until approximately 3 years. However, a statistically significant difference emerges thereafter. Specifically, Sequence1 indicates a high degree of nuclear power progression, which increases over time. The sequence variables for this are presented in Table 2. Fig. 5 illustrates the simulation results, reflecting nuclear power trends and data center prosperity. According to Fig. 5(a), Sequence1 shows a gradual increase from the beginning, then remains unchanged after a certain point. Conversely, Sequence2 initially peaks before gradually declining from around year 8. Statistics related to data centers are summarized in Table 3. The larger standard deviation observed when considering nuclear energy is interpreted as a reflection of the various policy uncertainties surrounding nuclear energy. Overall, these results clearly demonstrate the impact of nuclear energy load power on data centers.

4. Conclusions

Data centers that utilize nuclear energy have the advantage of being carbon-free energy, but more importantly, they are baseload power as sustainable power. This study has the following important points:

- Data centers are studied from the perspective of nuclear energy sources.
- Successful data centers are operated using nuclear energy.
- Energy sources required for the AI era are presented.
- Future nuclear power generation strategies that can be integrated with the IT industry are proposed.

As the AI industry grows rapidly, securing large-scale demand is essential, and existing fossil fuel-based power generation is being replaced by carbon-free nuclear power and renewable energy sources. At this point, the nuclear power industry is facing a new paradigm, and the third largest IT company has already started using power generated by nuclear power generation. The demand for nuclear energy is expected to increase in the future. In particular, modular SMRs can quickly adapt to various types of data centers and have enormous application potential. Building on the experience gained from large-scale nuclear power plants, advanced business strategies can be developed, and groundbreaking contributions to human well-being are anticipated.

Acknowledgments

This study was supported by the Ministry of SMEs and Startups grant (RS-2023-00266376).

REFERENCES

[1] Avison Yonug, Data center power demand to triple by 2030: Nuclear energy expected to reduce grid dependence. Avison Young Inc., Toronto, Canada, 2025, https://www.avisonyoung.us/w/data-center-energy-demand-to-triple-by-2030.

[2] Jackson, A., Top 10: Characteristics of Data Centres (Revisited), Data Centre Magazine, Norwich, UK, 2024, https://datacentremagazine.com/top10/top-10-characteristics-of-data-centres-revisited.

[3] Sullivan, K., Top Five Attributes Of A Successful Data Center, Forbes Media LLC, Jersey City, USA, 2016, https://www.forbes.com/sites/centurylink/2016/05/11/top-five-attributes-of-a-successful-data-center/.

[4] Future bridge, What is The Role Of Nuclear Energy In Powering Data Centers? Future Bridge s.r.o, Atlanta, USA, 2025, https://netzero-events.com/what-is-the-role-of-nuclear-energy-in-powering-data-centers/

[5] ANS, Amazon buys nuclear-powered data center from Talen. Nuclear News, American Nuclear Society, Westmont, USA, 2024, https://www.ans.org/news/article-5842/amazon-buys-nuclearpowered-data-center-from-talen/.

[6] Shaw, A., Microsoft and Constellation sign PPA for Three Mile Island restart, Power Technology, New York, USA, https://www.power-technology.com/news/constellation-microsoft-three-mile-island/?cf-view.

[7] WNN, Google to fund development of three nuclear power sites, World Nuclear News (WNN), World Nuclear Association, London, UK, 2025.

[8] Sterman, J.D., Business Dynamics: Systems Thinking and Modeling for a Complex World, Irwin McGraw-Hill, Boston, USA, 2000, https://www.world-nuclear-news.org/articles/google-to-fund-elementl-to-

prepare-three-nuclear-power-sites.
[9] Alkhalaf, A., Hussain, F.K., EleVMate — A data-driven approach for 'on-the-fly' horizontal small datacentre scalability and VM starvation. Fut. Gen. Comp. Syst. 159 (2024), pp. 91-101.
[10] Pfenninger, S., Keirstead, J., Comparing concentrating solar and nuclear power as baseload providers using the example of South Africa. Energy 87 (2015), pp. 303-314.
[11] De Rooij, D., Base Load and Peak Load: understanding both concepts. Sinovoltaics Group Limited, Hong Kong SAR, China, 2025, https://sinovoltaics.com/learning-center/basics/base-load-peak-load/.

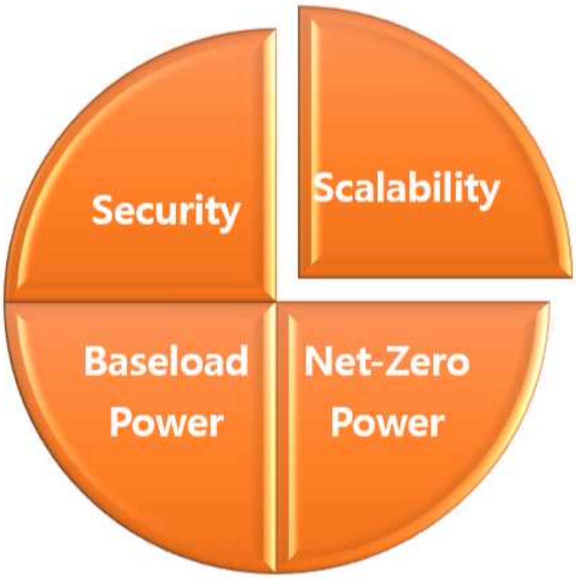


Fig. 1. Characteristic of nuclear-powered data center [4].

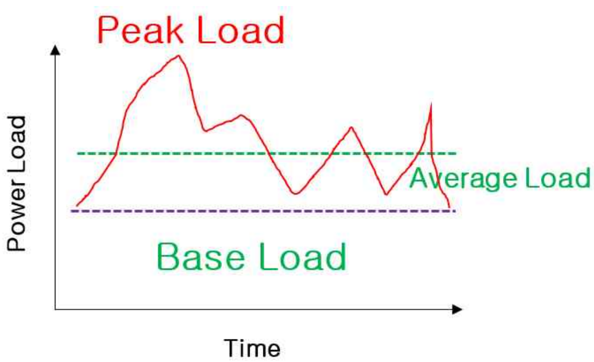
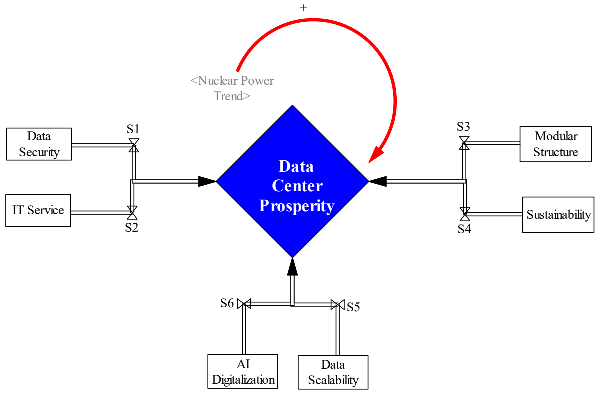
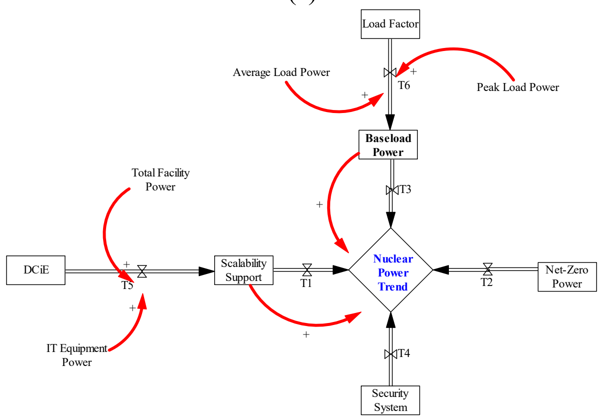


Fig. 2. Picture of base load and peak load [11].



(a)



(b)

Fig. 3. Modeling of SD (a) Data Center Prosperity and (b) Nuclear Power Trend.

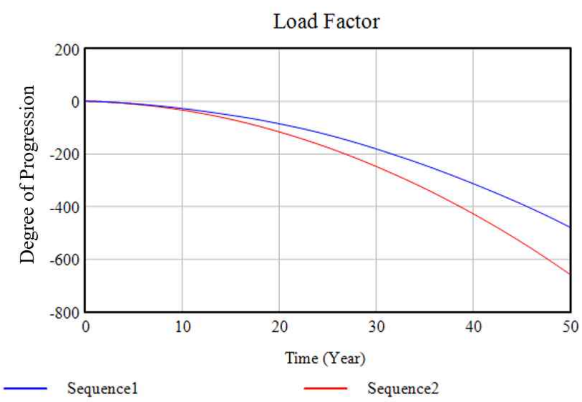
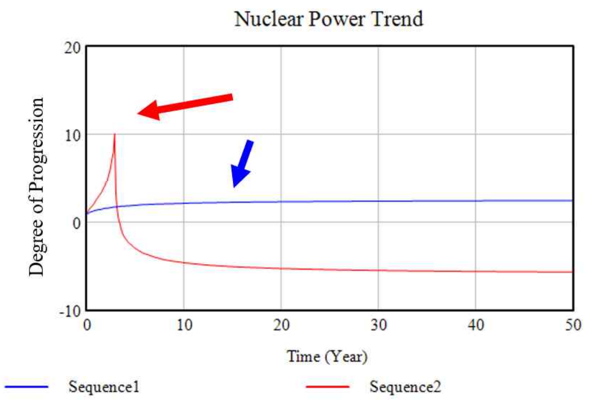
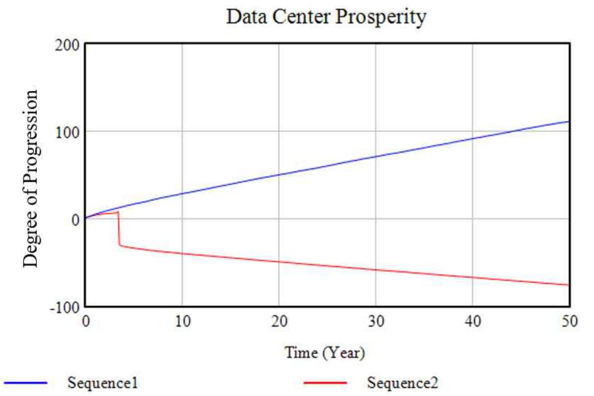


Fig. 4. Result of Load Factor.



(a)



(b)

Fig. 5. Result of simulations as (a) Nuclear Power Trend and (b) Data Center Prosperity.

Table I: Data center inventory of the United States [1].

Year	Power Demand (GW)
2022	19.3
2024	30.5
2026	43.6 (expected)
2028	62.1 (expected)
2030	88.6 (expected)

Table II: List of Base Load Power.

Sequence	Content
1	INTEG (T6-T3), Initial Value = 1.0
2	INTEG (-(T6-T3)), Initial Value = 1.0

Table III: Statistics of Data Center Prosperity.

Sequence	Min.	Max.	Mean	Median	St. Dev.
1	1	111.43	59.96	60.53	**30.80**
2	-75.62	8.75	-50.68	-53.74	**19.40**