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Systematic Literature Review (SLR): Nuclear Power Plants

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A B S T R A C T

Nuclear Power Plant (NPP) is a thermal power plant using one or several nuclear reactors as its heat source. NPP uses radioactive materials such as uranium as the heat source by utilizing fission reactions. The fission reaction produces enormous heat energy. Currently, there are many studies on NPPs, ranging from technological developments to the environmental impact of the NPP itself. This study aims to identify research developments on nuclear power plants from around the world obtained from relevant international journals in 2017-2023. The method used in this study is the Systematic Literature Review (SLR) method. The SLR method is used to identify, review, evaluate, and conclude all available research with interesting topic areas, with specific relevant research questions. Data were obtained by searching journals with Harzing's Publish or Perish application from the Scopus journal database. There are 191 journals with the keyword " Nuclear Power Plant " obtained from the Scopus database. Then these journals are filtered by type of article and if the number of citations is more than 32, then 49 articles are obtained which will be reviewed. This SLR method shows the development of research on NPP in several developed countries that have been using this technology for a long time. In addition, research topics such as the Fukushima accident, fault diagnostics, and safety assessment are the most discussed topics in the research so that they can be used as a reference for countries that are developing NPP.

1. INTRODUCTION

The use of renewable energy is being echoed in various countries as the choice of environmentally friendly energy and the dwindling availability of fossil energy. New and renewable energy is available in nature in abundant or unlimited quantities. NPP is a renewable energy that is currently considered one of the most reliable sources of electricity and has been proven to be sustainable and emit no carbon emissions during operation [1]. The NPPs reliability is proven in 50 countries that use a total of 440 nuclear reactors and can provide 10% of the world's electricity worldwide and this number will continue to increase [1].

There are two types of nuclear reactions, fusion reactions, and fission reactions. Fusion Reaction (a thermonuclear reaction) is a reaction in which two atomic nuclei combine to form one or more larger nuclei and subatomic particles (neutrons or protons). Nuclear fusion is a low-emission, low-carbon, low-

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waste energy source that could provide enough energy supply for all of humanity for millions of years. Fusion power plants would be inherently safe, with no risk of a major or serious nuclear accident, because an uncontrolled fusion reactions could be physically excluded from the fusion reactor. Extremely high fuel temperatures, which do not occur naturally on Earth, are required for energy-efficient fusion reactions. A major equipment failure or accident would result in cooling of the fuel and disruption of the ongoing fusion reaction. There would also be such a small amount of fuel in the reactor (only a few grams) that any fuel leakage would not be harmful to the environment if the reactor structure were damaged. Compared to all available industrial energy sources, including renewable energy, the environmental impact of fusion power generation is the lowest [2].

The DEMO2 model, which represents the most relevant prototype of a future fusion power plant, was used in the analysis because it currently represents one of the most accurate cost estimates of fusion power plant construction and operation. According to the model, a DEMO2 fusion power plant with a net electrical output of ~1 GW should provide about 6.3 TWh of electricity per year to the grid [3].

Nuclear fission is a nuclear reaction in which the nucleus of an atom splits into smaller pieces which often produce free neutrons and photons, the letter in the form of gamma rays. This reaction is used in NPPs. In conclusion, nuclear fuel (generally uranium) undergoes a fission reaction when bombarded by neutrons, which allows a chain fission reaction to occur which produces a large amount of energy.

Fission reactions that occur in nuclear reactors produce enormous heat. A nuclear reactor is a place where nuclear reactions take place in a controlled manner. Nuclear reactor components consist of fuel (uranium), reactivity, control, cooling water, and vessel. During the course of fission reaction, the reactor can release radiation. To prevent radiation from harming humans and the environment, nuclear reactors are placed within a building that is sturdy, safe, and has a multi-layered protection system. The heat is then used to heat water until it boils so that it turns into steam. The water vapor that is formed is then used to turn turbines and generators to produce electricity. Finally, the electricity produced is sent to the customer through the power grid.

2. METHODOLOGY

2.1 Object of research

The object of this study is the NPP. There are several reasons for choosing a nuclear power plant as an object of research, for example the NPP has a very large energy potential and low carbon emissions because it does not produce direct emissions during its operation. In addition to its enormous advantages, nuclear power plants also have a significant impact on the environment in the event of accident.

2.2 Research methods

2.2.1 Research question

- How many Scopus-indexed articles with NPP research were found in 2017-2023?
- What is the trend in the development of the number of Scopus-indexed articles with NPP research in the 2017-2023 range?
- How many citations are there from the Scopus-indexed articles with NPP research in the 2017-2023 range?
- Which countries reviewed NPP from the Scopus-indexed articles in the 2017-2023 range?
- What are the research focus groups on NPP from the Scopus-indexed articles in the 2017-2023 range?

2.2.2 Search Process

The search process was carried out on the Scopus database with the Publish or Perish application. The keyword used is "Nuclear Power Plant" by limiting the articles from 2017 to 2023.

2.2.3 Inclusion and Exclusion Criteria

At this stage, criteria are determined from the obtained data, whether the data is suitable for use as a data source for research or not. The following are criteria for data that is said to be suitable of being a research data source, namely:

- Data obtained within the 2017-2023 timeframe.
- Data obtained from the Scopus database through the Publish or Perish application.
- The data used only relates to NPP.

2.2.4 Quality Assessment

At this stage, the data that has been found will be evaluated based on the following criteria:

- Selected data only Article-type.
- Data with the types of Conference Paper, Letter, Book, and Review are omitted.
- The selected data are only from journal articles with more than 32 citations.

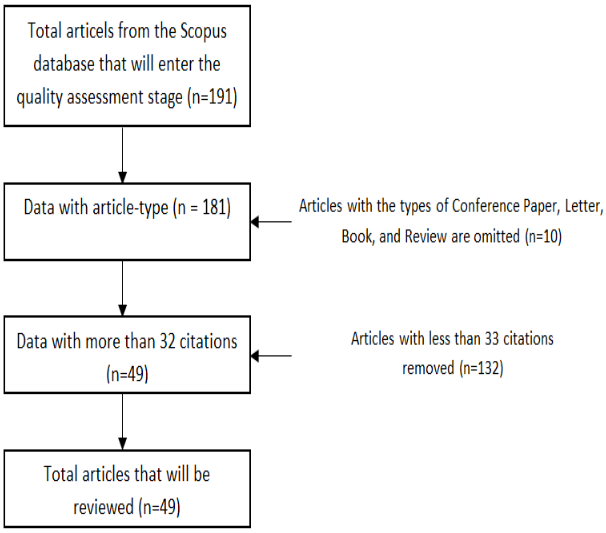

Fig. 1. Flowchart of selection of journals to be reviewed

2.2.5 Data collection

At this stage, the data needed in the research was collected for further analysis. The following are the steps for data collection:

1. Open the Publish or Perish application.
2. Select the Scopus search database.
3. Enter the keyword "Nuclear Power Plant".
4. In the “Year” column of the Scopus search, enter 2017 in the first box and 2023 in the second box. This indicates that the selected articles paper range is from 2014-2019.
5. Click the “Search” button and a database of Scopus articles on NPPs from 2017-2023 will appear.

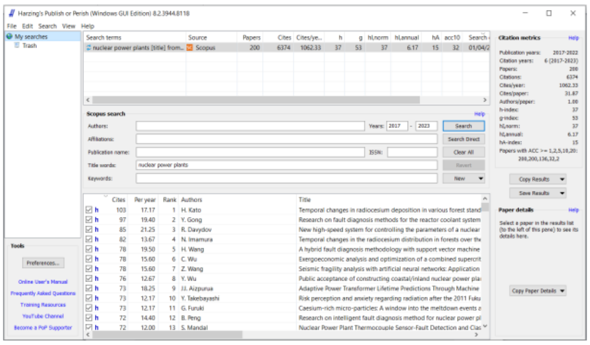

Fig. 2. Search results using Publish or Perish with the keyword *nuclear power plant*

2.2.6. Data analysis

The data that has been collected in the previous stage will be analyzed at this stage. The results will answer all the predetermined research questions.

2.2.7. Documentation

At this stage, the research results are written down in a paper form according to the format provided.

3. RESULTS AND DISCUSSION

From the results of the search process, inclusion and exclusion criteria, and quality assessment. 49 journal articles that were in accordance with the mix, namely Scopus-indexed journals in the 2017-2023 period with the topic "Nuclear Power Plant" were obtained. Table 1 display those journal articles.

Table 1. Articles that match the criteria

No _	To quote	Writer	Title	Year
1	103	H. Kato	Temporary changes in radiocesium deposition in various forest stands after the Fukushima Dai-ichi Nuclear Power Plant accident	2017
2	97	Y. Gong	Research on fault diagnosis methods for nuclear power plant reactor cooling systems based on the DS evidence theory	2018
3	82	N. Imamura	Temporal changes in the distribution of radiocesium in the forest during the five years after the Fukushima Daiichi Nuclear Power Plant accident	2017
4	78	H. Wang	Hybrid fault diagnosis methodology with support vector machining and better particle swarm optimization for nuclear power plants	2019
5	78	C. Wu	Exergoeconomic analysis and optimization of the Brayton/organic flash cycle supercritical carbon dioxide recompression combination for nuclear power plants	2018
6	78	Z. Wang	Seismic fragility analysis with neural networks: Applications for nuclear power plant equipment	2018
7	76	Y. Wu	Public acceptance of the construction of coastal/land nuclear power plants in post-Fukushima China	2017
8	73	JI Aizpurua	Lifetime Prediction of Adaptive Power Transformers Through Machine Learning and Uncertainty Modeling in Nuclear Power Plants	2019
9	73	G. Furuki	Caesium-rich microparticles: A window into the catastrophic events at the Fukushima Daiichi Nuclear Power Plant	2017
10	72	B. Peng	Research on intelligent fault diagnosis methods for nuclear power plants based on correlation analysis and deep trust networks	2018

11	72	S. Mandal	Detection and Classification of Nuclear Power Plant Thermocouple Sensors Using Deep Learning and Generalized Likelihood Ratio Tests	2017
12	70	M. Modarres	Advances in probabilistic risk assessment of multi-unit nuclear power plants	2017
13	63	A. Ayodeji	Knowledge base operator support system for fault diagnosis of nuclear power plants	2018
14	60	Y. Guo	Unknown to me then: Local acceptance of China's planned nuclear power plant in the post-Fukushima era	2017
15	55	S. Yamashita	Lessons from Fukushima: Latest Findings of Thyroid Cancer After the Fukushima Nuclear Power Plant Accident	2018
16	53	S. Iwagami	Contribution of radioactive 137Cs release by suspended sediment, coarse organic matter, and dissolved fraction from the upstream catchment in Fukushima after the Fukushima Dai-ichi Nuclear Power Plant accident	2017
17	52	O. Siddiqui	Comparative environmental impact assessment of nuclear, wind and hydro-electric power plants in Ontario: Life cycle assessment	2017
18	51	A. Ochiai	Uranium Dioxide Fragments and Debris Released into the Environment with Cesium-Rich Microparticles from the Fukushima Daiichi Nuclear Power Plant	2018
19	50	W. Jung	HuREX – A framework for collecting HRA data from simulators in nuclear power plants	2020
20	50	J. Imoto	Isotope signature and cesium-rich microparticle nanotexture: Release of uranium and fission products from the Fukushima Daiichi Nuclear Power Plant	2017
21	47	V. Yoshchenko	Distribution and flux of radiocesium in a typical forest of Cryptomeria japonica in late stages after the accident at the Fukushima Dai-Ichi Nuclear Power Plant	2017
22	45	G. Wu	Framework for fault diagnosis with multi-source sensor nodes in nuclear power plants based on Bayesian networks	2018
23	45	DS Kim	Multi-unit Level 1 probabilistic safety assessment: The approach and its application to a six-unit nuclear power plant site	2018
24	43	D. Lee	Autonomous operating algorithm for nuclear power plant safety systems using short-term memory and a function-based hierarchical framework	2018
25	42	A. Naserbegi	New exergy optimization of the Bushehr nuclear power plant with the gravity search algorithm (GSA)	2018
26	42	S. Iwagami	Temporal changes in dissolved 137Cs concentrations in groundwater and river water in Fukushima following the Fukushima Dai-ichi Nuclear Power Plant accident	2017
27	40	F. Sorgulu	Cost evaluation of two potential nuclear power plants for hydrogen production	2018
28	38	HP Nguyen	Devising empirical mode decomposition and short-term memory neural networks for multi-step prediction of time series signals in nuclear power plants	2021
29	38	C. Xiang	Single-phase high-entropy alloy design consisting of low thermal neutron absorption cross-sectional elements for nuclear power plant applications	2019
30	37	G. Lee	Convolutional neural network model for the diagnosis of abnormalities in nuclear power plants	2021
31	37	K. Saito	Summary of temporary changes in airborne dose rate and radionuclide deposition density in the 80 km zone over the five years after the Fukushima Nuclear Power Plant accident	2019
32	37	J. Takahashi	Monitoring of the vertical distribution of radiocesium for six years in three forest lands after the Fukushima Dai-ichi Nuclear Power Plant accident	2018
33	37	R. Ikehara	A New Method for Measuring Radioactive Cesium-Rich Microparticles (CsMPs) in the Environment of the Fukushima Daiichi Nuclear Power Plant	2018
34	36	Y. Sato	Intercomparison of 137Cs Atmosphere Models From the Fukushima Daiichi Nuclear Power Plant Accident: Simulation Based on Identical Input Data	2018
35	36	CZ Huang	Inappropriate programming of fuzzy stochastic opportunity constraints for emergency evacuation at Qinshan nuclear power plant under uncertainty	2017
36	36	W. Li	Fault detection, identification and reconstruction of sensors in nuclear power plants with an optimized PCA method	2018

37	35	J. Park	Linkages between performance shaping factors for human reliability analysis of nuclear power plants	2020
38	35	S. Hancock	Transgeneration effect of historic radiation dose on pale grass blue butterflies in the vicinity of Fukushima after the accidental destruction of the Fukushima Dai-ichi Nuclear Power Plant	2019
39	35	H. Tsuruta	Time series analysis of atmospheric radiocesium at two SPM monitoring sites near the Fukushima Daiichi Nuclear Power Plant just after the Fukushima accident on March 11, 2011	2018
40	35	MB Roth	Going nuclear for climate mitigation: A cost-effectiveness analysis of conserving existing US nuclear power plants as a carbon avoidance strategy	2017
41	34	AKS Ong	Investigating the acceptability of reopening the Bataan nuclear power plant: Integrating protective motivation theory and extended theory of planned behavior	2022
42	34	SW Kim	Evaluation of seismic fragility of nuclear power plant piping systems on an isolated basis using stress-strain based failure criteria	2019
43	34	M. Čepin	Evaluation of the reliability of the electric power system if the nuclear power plant is replaced by a wind power plant	2019
44	34	N. Fathi	Increasing the efficiency of a solar chimney power plant by utilizing waste heat from nuclear power plants	2018
45	34	T. Kong	Radioactive waste released from the Korean nuclear power plant and the resulting radiation dose to members of the public	2017
46	34	Y. Zou	Human Reliability Analysis for Digital Nuclear Power Plants: A Case Study of the LingAo II Nuclear Power Plant	2017
47	33	W. Li	Improved PCA method for detection and isolation of sensor faults in nuclear power plants	2019
48	33	T. Sakurahara	Integrated methodology for spatio-temporal incorporation of underlying failure mechanisms into probabilistic risk assessment of nuclear power plant fires	2018
49	33	N. Casacuberta	Potential Release of Isotopes 129I, 236U, and Pu from the Fukushima Dai-ichi Nuclear Power Plant into the Ocean from 2013 to 2015	2017

Journal articles in Table 1 are sorted by the most citations from 2017-2023. Of the 49 articles that met the criteria, no journal articles published in 2023 were found. Figure 3 shows the number of articles published each year, which tends to decrease. The largest number of publications was in 2018 with a total of 19 articles, followed by 2017 with a total of 17 articles. Then, article publications experienced a drastic decline in 2019 with a total of 8. The decline continued until 2020 and 2021, where the former published 2 articles and leaving only 1 article in 2022. In 2023, there is no article about "nuclear power plants" published that met the aforementioned criteria.

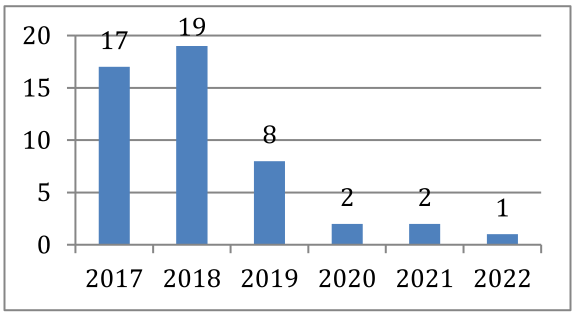

Fig. 2. Number of journal articles published per year

Meanwhile, the number of article citations per year follows the trend of the number of articles that have been published as shown in Fig. 4. The most-cited articles were in 2018 with a total of 957, followed by 2017 with a total of 952. Then article citations experienced a drastic decline in 2019 with a number of 362. The decline continues until 2020 with 85, in 2021 with 75 citations, and finally 34 citations in 2022.

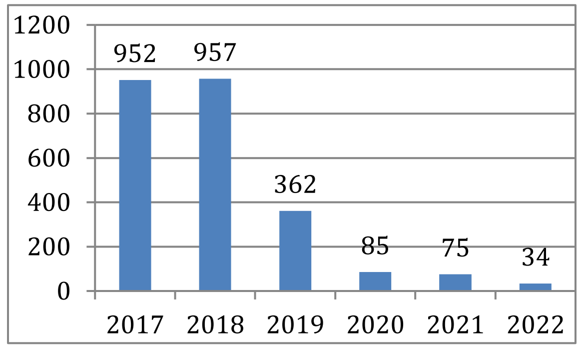

Fig. 3. Number of journal citations per year

Based on the source, publication those 49 articles from 2017-2023 related to "nuclear power plants" can be grouped as shown in Table 2. The journal that published many topics on "nuclear power plants" is *Nuclear Engineering and Technology*, which publishes article on that topic almost every year except 2022. Then *The Journal of Environmental Radioactivity* published 6 articles, followed by *Annals of Nuclear Energy* and *Reliability Engineering and System Safety*, each published 4 articles. Furthermore, *Environmental Science and Technology* and *Scientific Reports* published 3 articles and the rest published 1 to 2 articles.

Table 2. Grouping based on article sources

Journal Source	Year						Total
	2017	**2018**	**2019**	**2020**	**2021**	**2022**	
History of Nuclear Energy		4					4
Applied Energy					1		1
Applied Soft Computing					1		1
Energy	1	1					2
Energy Conversion and Management		1					1
Energy Policy	2						2
Engineering Structure		1					1
Environmental Research			1				1

Environmental Science and Technology	1	2					3
Journal of Geochemistry		1					1
IEEE Transactions in the Electronics Industry			1				1
IEEE Transactions on Nuclear Sciences	1						1
Intermetallic			1				1
International Journal of Hydrogen Energy		1					1
ISA transactions			1				1
Journal of Net Production	1	1					2
Journal of Environmental Informatics	1						1
Journal of Environmental Radioactivity	4	1	1				6
Journal of Geophysics Research: Atmosphere		1					1
Nuclear Engineering and Technology	2	1	2	1		1	7
Nuclear Energy Advances		2					2
System Reliability and Security Engineering	1	1	1	1			4
Scientific Reports	3						3
thyroid		1					1
Total	**17**	**19**	**8**	**2**	**2**	**1**	**49**

Table 3 presents 49 articles by country of origin of the main authors. Japan is the largest country of origin with a total of 16 articles from the 2017-2019 range. China is the second largest country after Japan with 14 articles in the same timeframe. They are followed by South Korea which was quite consistent by publishing 7 articles from 2017-2021. Furthermore, the United States produced 4 articles in the 2017-2018 range. Finally, eight countries including India, Iran, Canada, Philippines, France, Scotland, Slovenia, and Turkey have published 1 article each.

Table 3. Grouping of journals by country

Country	**Year**						**Total**
	2017	**2018**	**2019**	**2020**	**2021**	**2022**	
China	4	7	3				14
India	1						1
Iran		1					1
Japan	8	6	2				16
Canada	1						1
South Korea	1	2	1	2	1		7
Philippines						1	1
French					1		1
Scotland			1				1
Slovenia			1				1
Türkiye		1					1
US	2	2					4
Total	**17**	**19**	**8**	**2**	**2**	**1**	**49**

Fig. 5. shows article grouping based on the topics of discussion raised in the research. The grouping of research topics in this journal is divided into 11 topics.

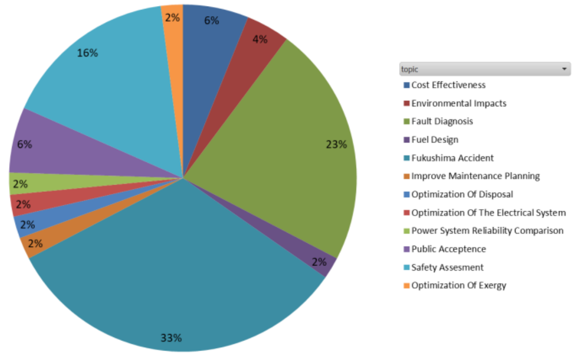

Fig. 4. Percentage of the number of research topics

The research topic that was mostly taken from the 49 Scopus-indexed articles with a percentage of 33% was "Fukushima Accident," namely the discussion related to the Fukushima Daiichi nuclear disaster in Japan. The next topic with 23% occurrences was related to "Fault Diagnostics" which discussed various failure diagnostic methods in the NPP system. Then, 16% of the research topics regarding "Safety Assessment" which discuss assessments related to system safety. Furthermore, 6% of research topics on "Cost-Effectiveness" discussing cost-effectiveness, and "Public Acceptance" discusses public responses around nuclear power plants. Finally, 4% of the topic of discussion is on "Environmental Impact" which discusses environmental impacts, as well as 2% on the topic discussion on "Fuel Design," "Improve Maintenance Planning," "Optimization of Disposal," "Optimization of Exergy," "Optimization of The Electrical System," and "Power System Reliability Comparison."

Table 4. Grouping of topics of discussion with research countries by year

Discussion Topic	**Year**						
Country	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**Total**
Cost-effectiveness							
China		1					1
Türkiye		1					1
US	1						1
Environmental Impact							
Canada	1						1
South Korea	1						1

Fault Diagnosis							
China		6	2				8
India	1						1
South Korea			1		1		2
Fuel Design							
China			1				1
Fukushima accident							
Japan	8	6	2				16
Improve Treatment Planning							
French					1		1
Disposal Optimization							
US		1					1
Exergy Optimization							
Iran		1					1
Electrical System Optimization							
Scotland			1				1
Comparison of Electrical Power System Reliability							
Slovenia			1				1
Public Acceptance							
China	2						2
Philippines						1	1
Safety Assessment							
China	2						2
South Korea		2		2			4
WE	1	1					2
Total	**17**	**19**	**8**	**2**	**2**	**1**	**49**

Based on Table 4, the most discussed topics discussed the nuclear disaster that occurred in Fukushima, Japan, in as many as 16 articles. All of these journals were discussed by Japanese researchers in the 2017-2019 period. From 2020 until now there have been no researchers from Japan or from other countries discussing the nuclear disaster in Fukushima. As a major article on the "Fukushima Accident", it discusses the spread and content of radioactive materials such as radiocesium at the location around the Fukushima nuclear plant. Articles [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], and [14] describe changes in the content of radioactive materials in locations such as forests around the nuclear power plant starting from trees, soil and air currents to the rivers and oceans around it. Articles [15] and [16] discuss methods for melting nuclear fuel and analysis of microparticles released into the environment as a result of the incident. The article [17] discusses cases of thyroid cancer that occurred in residents around the nuclear plant after the accident to understand the long-term impact on public health. Article [18] conducted a comparison of the simulation model of the distribution of cesium-137 in the atmosphere. Article [19] summarizes the results of research on the impact of radiation on pale blue grass butterflies around the power plant area.

The topic of "Fault Diagnosis" was most widely discussed by researchers from China totaling 8 articles, researchers from South Korea 2 articles, and researcher from India 1 article. Articles on this topic discuss various methods for diagnosing NPP system damage. The damage diagnosis methods for NPP used in the research include: a hybrid method that combines Support Vector Machine (SVM) and Improved Particle Swarm Optimization (IPSO) [20]; Artificial Intelligence methods such as Deep Belief Network (DBN) and correlation analysis [21], Bayesian Network [22], and Convolutional Neural Network (CNN) [23]. Another study discusses the diagnosis of damage to the nuclear reactor cooling system with the Dempster-Shafer theory (DS theory) [24]. Then, a discussion of the sensors installed on the NPP using methods such as Deep Learning and the Generalized Likelihood Ratio Test (GLRT) [25]; optimization of the PCA (Principal Component Analysis) method [26, 27]. Next is a discussion of seismic protection in security design and risk evaluation using the Artificial Neural Networks (ANN) method [28] and stress-strain based failure criteria [29]. The final method used in diagnosing damage to NPPs is a Knowledge Base Operator Support System [30] which consists of technical information, experience, and expert knowledge in the form of rules used to diagnose faults. The results of research on "Fault Diagnosis" show an increase in the accuracy of fault diagnosis in nuclear power generation systems.

"Safety Assessment" is the next most discussed topic, there are 8 Scopus-indexed articles published from various countries such as South Korea with 4 articles, China with 2 articles, and the United States with 2 articles. The discussion in the article on this topic is related to risk analysis in terms of the safety of an NPP. The research discusses advances in the Probabilistic Risk Assessment (PRA) method [31] and the Probabilistic Safety Assessment (PSA) approach [32] are used to identify, measure, and manage risk in NPP operations. Discussion of the HuREX framework used to collect Human Reliability Analysis (HRA) data for understanding the human contribution to risk in NPP operations using a simulator [33], the relationship between Performance Shaping Factors (PSFs) in human reliability analysis of the factors that affect human performance in the work environment [34], and analysis of human reliability in a digitized NPP environment [35]. Then research on risk analysis with the Long-Short Term Memory (LSTM) algorithm approach to predict future system conditions and a function-based hierarchical framework for making decisions based on these predictions [36] and Fuzzy Stochastic programming to identify emergency calls at NPP [37]. Next is the discussion regarding the integrated methodology for changing the failure mechanism in the NPP fire risk analysis [38].

Research topics on "Cost Effectiveness" and "Public Acceptance" amount to 3 articles each. "Cost Effectiveness" was discussed by researchers from China, Turkey, and the United States in 2017-2018, while "Public Acceptance" was discussed by researchers from China with 2 articles in 2017 and The Philippines with 1 article in 2022. Articles with the topic “Cost-Effectiveness” discuss the assessment of thermodynamic efficiency and economic aspects of the system by optimizing the combination cycle of Brayton recompression/organic flash cycle using supercritical CO_2 working fluid [39]; cost evaluation of two NPPs for hydrogen production from a particular mixture such as the type of nuclear reactor used, the hydrogen production technology chosen, and other potentially relevant factors [40]; and cost-effectiveness analysis of maintaining existing nuclear power plants as a strategy to avoid carbon emissions [41]. Then, research with the topic "Public Acceptance" discusses public acceptance of the construction of the NPP in China after the nuclear disaster in Fukushima [42, 43] and the rebuilding of the Bataan NPP in The Philippines [1] with research methods such as surveys, interviews or observations to collect data from local communities who are involved or potentially affected by the plan to build an NPP.

The research topic "Environmental Impact" has a total of 2 published articles. The topic "Environmental Impact" was discussed by researchers from Canada and South Korea in 2017. The journal with the topic "Environmental Impact" discusses a comparative analysis of the environmental impact of NPP, wind power, and hydro-electric power in Ontario using the Life Cycle analysis method. Assessment (LCA) [44], as well as an analysis of the spraying of radioactive waste from the NPP and the radiation dose received by the general public as a result of this spraying [45]. While topics with 1 article each such as "Fuel Design" from China in 2019, "Improve Maintenance Planning" from France in 2021, "Optimization of Disposal" from the United States in 2018, "Optimization of Exergy" from Iran in

2018, "Optimization Of The Electrical System" from Scotland in 2019, and "Power System Reliability Comparison" from Slovenia in 2019. Discussion of some of these topics such as the design of multicomponent alloys High-Entropy Alloys (HEA) with neutron absorption crossbars low thermal [46], use of the Ensemble Empirical Mode Decomposition (EEMD) method and Long Short-Term Memory (LSTM) Neural Network for multistep prediction of time series signals which are useful for helping in optimizing NPP operations and maintenance [47], optimizing exergy in The NPPs using the Gravitational Search Algorithm (GSA) [48], improving the efficiency of solar chimney power generation by using waste heat from the NPP [49], the use of machine learning and angling modeling to predict the power lifetime of adaptive transformers within the NPP [50], and evaluation of the reliability of the electricity system if an NPP is powered by a wind power plant [51].

4. CONCLUSION

Based on the results of the research that has been done, it can be concluded that the results of the Systematic Literature Review or SLR of the 49 articles published by Scopus-indexed journals from 2017-2023 regarding "Nuclear Power Plants" have decreased from 2017 and there are no articles published in 2023. The article mostly discusses the impact after the nuclear disaster in Fukushima, Japan, but this discussion only reaches 2019 and there are no article publications about the nuclear disaster until 2023. The article mostly discussion of the Fukushima accident is no longer discussed after 2019 because the impact of the accident cannot be felt for now. Reflecting on the Fukushima nuclear disaster, researchers are discussing how to detect system damage and risk analysis in terms of security. This is done in order to reduce the risk of disaster and the impact of losses caused by nuclear plant accidents so that technological developments in nuclear plants can continue.

Research on NPPs is mostly carried out by developed countries such as Japan, China, South Korea, and the United States with at least 4 articles while other developed countries such as Canada, France, Scotland, and Slovenia only published 1 article. Meanwhile, developing countries that have started to conduct research related to NPPs such as India, Iran, the Philippines, and Turkey. In general, the reduction in research on NPPs is due to several issues such as security issues, environmental issues, regulations and policies, and the development of renewable energy. But, the situation and circumstances may vary for different countries. It depends on national energy policies, energy needs, public acceptance, and other factors. While research on nuclear power generation may be on the decline, this does not mean that research in this field has completely stopped around the world. There are countries that are still active in research and development of nuclear technology for energy and other applications.

AUTHOR CONTRIBUTION

Muhammad Reza Maulana Aliva: Conceptualization, Methodology, Data curation, Investigation, Writing - original draft. Nofiyendri Sudiar: Data curation, Investigation, Validation. Hamdi: Supervising, Validation, Writing – review & editing.

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