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Key Research Areas and Trends in Bibliometric Analysis of Microgrids

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Abstract: **-** Microgrids represent a novel breed of sustainable energy sources that have gained widespread adoption within the energy domain. This investigation employs bibliometric analysis techniques to scrutinize prior scientific publications on microgrids, utilizing quantitative and statistical methodologies to unveil distribution trends of articles across specific themes and time frames. Furthermore, the exploration pinpoints principal contributors and collaborative trends within the field. The findings of this study reveal a noteworthy surge in scholarly publications pertaining to intelligent grid frameworks, with a particular emphasis on cutting-edge technologies and multidisciplinary partnerships. Furthermore, the study highlights the adoption of blockchain technology in smart grids and the inclusion of renewable energy sources into microgrids. Moreover, this scholarly inquiry furnishes researchers and industry professionals with valuable insights into the current technological landscape and prospects for future research endeavors.

Keywords: Microgrid, Smartgrid Technologies, Bibliometric Analysis, Microgrid Evolution, Key Contributors Identification

I. INTRODUCTION

Microgrid systems consist of several key components and technologies that enable their efficient and flexible operation within the electrical network [1,2]. According to Recabert et al [1], microgrids are composed of distributed generation (DG) systems, energy storage systems (EES), and loads that are electrically interconnected and hierarchically controlled. These DG systems include renewable sources such as wind and photovoltaic power plants, which are well-suited for integration due to their scalability and potential connection points within the power system [3]. Additionally, non-renewable-based power systems like diesel or gas-fueled generators can be integrated into microgrids, offering controllability of generation profiles [4]. This research evaluates past microgrid literature through bibliometric analysis methods using quantitative and statistical approaches to generate distribution patterns of articles in certain issues and periods. The goal of doing a bibliometric analysis on microgrid technology and application is to identify the important research issues and areas of attention within this subject. These can allow industry experts and researchers to identify which components of microgrid technology have been investigated and which areas need more attention. It can also assist in finding any gaps in research and indicate promising topics for future research and growth. In order to address the following research questions (RQs), this study focuses on the bibliometric analysis of scientific publications relevant to microgrids: RQ1: How is the spread and advancement of microgrid research now going? RQ2: What are the topic areas and themes in microgrid research? RQ3: Who are the main contributors to microgrid research? RQ4: What is the current collaboration pattern in microgrid studies? RQ5: What are the most influential documents in microgrid literature?

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II. LITERATURE REVIEW

2.1 Bibliometric Analysis

According to [5], bibliometric analysis is a study that uses quantitative and statistical methods to generate patterns of article distribution in certain problems and periods. Bibliometric studies are used to present trends and patterns of one research topic. The bibliometrics analysis method is now popular as a research method to present the trends and impacts of a study [6]. The indicators commonly used in bibliometric studies are publication classification, citation, authorship, publication impact, and country [7]. [8] divide the indicators of bibliometric studies into three, namely, quantity, quality, and structural indicators. Quantity indicator indicates the productiveness of researchers. Quality indicators relate to the performance of the researcher's output reflected through the number of citations or citations per year, the total h-index or g-index, and the citation score.

Research quality indicators can also be seen from the impact of publications (IPP) and the impact factors (IF) [9]. Structural indicators relate to the relationship between publications, authors, and research fields. This indicator can also be measured by analyzing co-authorship, co-citation, and bibliographic coupling [10].

2.2 Evolution of Research on Microgrids

The evolution of microgrid research has followed the technological advancements and practical applications of these localized energy systems [3]. Early microgrid research concentrated on understanding the dynamics of isolated power systems and determining the technological feasibility of connecting them into the main grid. As the notion of microgrids gained popularity, research focused on enhancing their operation and control. Scientists have conducted experiments on cutting-edge control algorithms, grid integration methods, and power management tactics in order to enhance the efficiency and reliability of microgrids [9]. With the growing utilization of renewable energy sources within microgrids, studies have progressed to tackle the challenges and possibilities associated with integrating variable generation from solar and wind power. Past research has considered microgrids as a realistic option for integrating decentralized energy resources. Hirch et al [11]. elucidated that microgrids consist of clusters of loads, decentralized energy resources (such as PV panels and diesel generators), and energy storage systems (such as batteries and flywheels) that collaborate to deliver electricity in a reliable manner. Microgrids have the capability to be linked to the distribution grid or function in islanding mode, where energy is exchanged locally among loads, DERs, and ESSs [2]. The article also mentioned that microgrids offer advantages like dependability and cost-efficiency. Furthermore, it emphasizes the utilization of blockchain technology as a promising approach for implementing control and business processes within microgrids.

Currently, the exploration on microgrids is focused on cutting-edge technologies like artificial intelligence, machine learning, and blockchain with the goal of improving grid optimization, proactive maintenance, and decentralized energy trading within microgrid networks. Moreover, interdisciplinary research partnerships are anticipated to drive progress in the areas of policy, economics, and societal impacts of microgrid implementation, fostering a comprehensive comprehension of the overall influence of microgrids on energy systems and society. The work by [11] envisions a future smart grid enabled by blockchain, demonstrating the potential applications of blockchain in power trading, energy markets, and decentralized energy resources. The article presents an extensive examination of the swiftly advancing blockchain technology in smart grid studies, providing a succinct overview of blockchain origins, key requirements for smart grids, concerns regarding security and privacy, and the effects of blockchain technology on the energy industry.

Musleh et al [12] investigate the application of blockchain technology in smart grids, presenting an overview of the technology, its fundamental principles, and its diverse applications outside the realm of smart grids. The analysis conducted in the article delves into the utilization of blockchain within smart grids, encompassing diverse validation methodologies. Furthermore, it delves into recent industrial applications and puts forth a prospective trajectory for future advancements. The discussion also touches upon microgrid technologies concerning blockchain applications in the context of smart grids. Various components within microgrids, such as smart metering aggregators, wind energy aggregators, and energy storage aggregators, can each possess individual blockchains. These blockchains contribute towards endowing microgrids with enhanced flexibility, reliability, and a secure operational and control framework. The integration of blockchain technology fosters heightened trust levels between microgrid proprietors and utilities. Musleh et al. also discuss the relevance of demand-driven control and the optimized operation of microgrids, especially considering the incorporation of distributed energy resources (DERs). The exploration of microgrid systems in research has witnessed notable progression in terms of scholarly output and influence over time. As indicated by Musleh et al [12], the quantity of academic publications focusing on microgrid systems has experienced a marked rise, exhibiting an annual growth rate of approximately 8.23%. This considerable surge underscores an escalating interest in and recognition of this field of study within the academic community. Moreover, the authors' analysis revealed that Aalborg University, in Denmark, has made significant contributions to this research topic and highlights solid social networks and collaborations among top authors. Additionally, the study conducted by Tambunan et al [13] utilized bibliometric network analysis to identify trend topics and map the evolutionary path of research related to microgrid systems from 2010 to 2021. This underscores how research trends have evolved, providing valuable insights into the progression and impact of scholarly work in this domain. Table 1 shows some of the previous studied done in microgrids.

Table 1: Previous bibliometric analyses on microgrid-related studies

Author	Domain or search strategy	Data source and scope	TDE	Attribute Examined
Tambunan et al. [14]	A."microgrid" OR "AC microgrid" OR "alternating current microgrid" OR "microgrid system" B "DC microgrid" OR "direct current microgrid" C "hybrid microgrid" OR "AC/DC microgrid" OR "AC-DC microgrid" OR "ac-dc microgrid"	Scopus (2010 2021)	4747	The analysis involved descriptive analysis, authors analysis, sources analysis, words analysis, and evolutionary path mapping.
Ante et al. [15]	Distributed ledger Energy markets, Smart grids, Electricity, Energy trading, Microgrids, Data privacy, Social network analysis, Bitcoin	Scopus	166	The research paper employed co-citation analysis to explore the intersection of blockchain and energy. This method helped identify key research streams and influential articles in the field .
Tahir et al [16]	Renewable energy sources, Hybrid energy system, Microgrid, Multi-objective optimization	Scopus (2010 to 2023)	2600	This combines scientific mapping and assesses the impact of citations. The relationships among authors, documents, and disciplines were evaluated.

III. METHODOLOGY

3.1. Data Source

This study is based on bibliometric analysis methodologies, which use quantitative and statistical approaches to determine patterns of article distribution in specific issues and [17] analyzed time periods. The Scopus database served as the primary source of bibliographical data for the microgrid literature. Scopus is preferred because to its powerful search capability, coverage of over 5000 publications, and high article quality requirements [18, 19]. Scopus's newly updated (October 2019) content coverage guide4 reveals that it includes around 23,452 active journal titles, 120,000 conferences, and 206,000 books from over 5000 foreign publishers.

Currently, Scopus has a literature database that has 60 million items from a range of fields, 23,700 peer-reviewed journals with 24,000 titles, 360 trade publications, 750 book series, and 195,000 non-serial volumes [20]. The goal of this enormous database is to provide a global overview of microgrid research. A total of 405 documents were analyzed using predetermined keywords.

3.2. Data Collection

The research method begins by looking up the keywords “microgrid” or” smartgrid” in the Scopus database using the article title. This study includes all types of documents obtained from the Scopus database between 2002 and 2023 (as of March 24, 2024). Thus, the Scopus database has been searched using the query TITLE (” microgrid” OR” smartgrid” AND” technology” AND ”application”). The search yielded 1482 documents from the microgrid literature. We can presume that not all the publications obtained are concerning microgrids because the search query was made using the article title, keywords, and abstracts. After the screening, 95 documents were eliminated because they were not in English, and 11 published 2024. So, all 1376 documents were eligible. Figure 1 illustrates the flow of the search strategy of this study.

3.3. Data Analysis

This study uses the analysis feature on the Scopus database and tools such as Microsoft Excel for quantitative calculations, such as the frequency of published documents, and to construct appropriate charts and graphs. Publish or Perish assesses publication impact and performance using specified metrics, while VOSviewer maps and visualizes bibliometric networks. This research has strategized the data analysis to address the RQs raised in the previous section. The first study looked at publications by year, source and type of document, and source title to answer RQ1. To respond to the RQ2, the subject areas and keywords used by the author were examined. To address RQ3, a network visualization map of author and country co-authorship was shown. Lastly, the top 20 highly cited documents answered the RQ4.

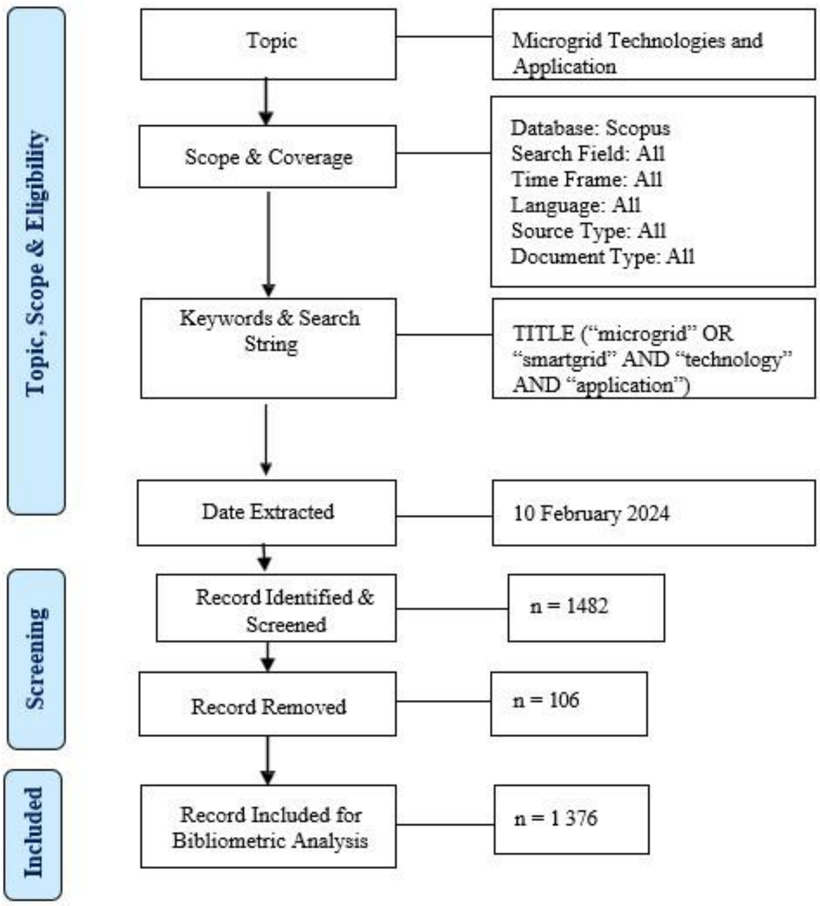

Figure 1: Flow chart for study selection

IV. RESULTS

4.1 Data Source

This section discusses the results based on the research questions that have been highlighted in the introduction section.

4.2 Development of Microgrid Research and its Distribution

To answer the RQ about the development of microgrid research and its distribution, this study analyses the following data: (a) publications by year, (b) the source and type of document, and (c) source title.

4.2.1 Publication by Year

Figure 2 shows the statistics of the annual publication of microgrid research from 2002 to 2023. The annual growth rate of the microgrid literature is retained at 29.08%. The first document was written by Smallwood, which classifies Microgrids according to their mode of operation which can be autonomous or non-autonomous. In the autonomous mode, the microgrid serves the electrical load without power from the utility, acting as its own stand-alone grid. In the non-autonomous mode, the microgrid produces power while interconnected to the utility system. The establishment of both autonomous and non-autonomous microgrids is possible, but there are technical and non-technical concerns that may affect their creation [21].Up until 2006, the advancement of microgrid research came to a halt. During this time, not many documents were published. There were only 7 documents throughout the first 5 years (2002–2006), or an average of 1.4 documents annually. Nevertheless, even though Western academics were the ones who initially developed microgrid research, it gradually extended to nations in Asia, Africa, and Europe. From 2007 till the present, research on the topic of microgrids has been intensely and widely pursued. Microgrid documents increased significantly during this time. The number of publications, which stands at 1381 documents with an average annual growth of 86 papers, attests to this fact. The quantity of documents increased steadily between 2007 and 2023. This shows the growing significance, attention, and relevance of microgrid.

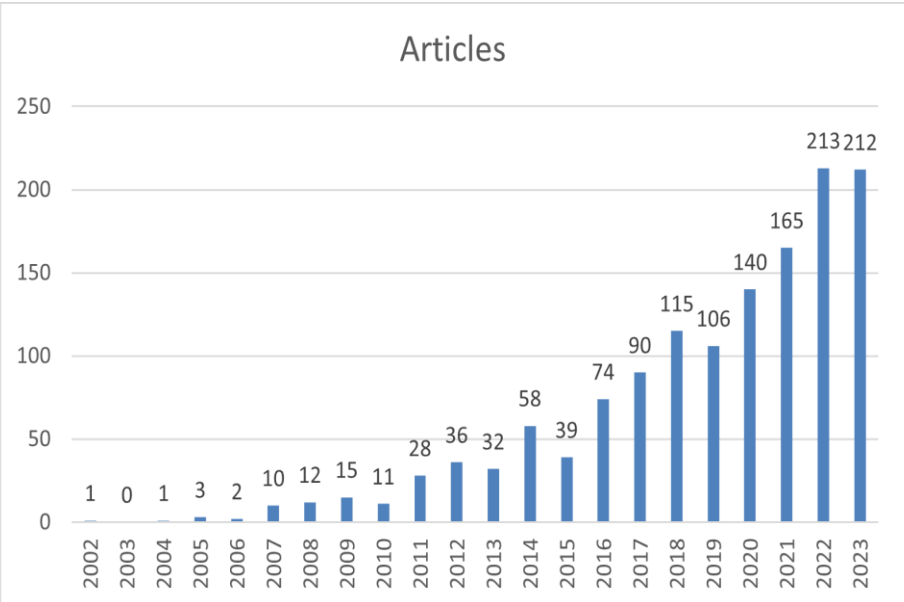

Figure 2: The growth of microgrid studies from 2002 until 2023

4.2.2 Source and Type of Document

This study also seeks to identify where microgrid research documents are published by analyzing the data by type of source document. Table 2 shows that journals are the dominating source at a (322: 79.5%). The trade journals are the least to publish on Microgrids at (1:0.01%).

Table 2: Source types of microgrid research

Source type	**Number documents**	**Percentage**
Journal	322	79.51
Conference Proceeding	39	9.63
Books	30	7.41
Book Series	13	3.21
Trade Journal	1	0.1
Total	405	100.00

Data is further analysed by document type in Table 3 below. It is evident from the information in the table that microgrid documents are dominated by research publications, as many as 1376 documents, consisting of 300 (74.07%) documents in the form of articles and 46 (11.36%) documents presented at conferences or symposiums. Documents in the form of book chapters are 35 (8.64%), and review documents are 22 (5.43%), while books and editorials are represented by only 1 document (0.25%).

Table 3: Document types of published literature in microgrid

Document type	Number documents	Percentage
Articles	300	74.07
Conference Proceeding	46	11.36
Books Chapters	35	8.64
Review Documents	22	5.43
Books and Editorials	1	0.25
Total	1376	100.00

4.2.3 Source Titles

Table 4 below, provides information of top source titles that published five or more documents on microgrid. The journal Energies contributed the largest number of publications with a contribution of 61 (4.43%.) documents. In the second place is the IEEE Excess which contributed 39 (2.83%) documents. The Applied Energy journal contributed 26 (1.89%) publications, and the Renewable and Sustainable Energy Reviews 25(1.82%) documents.

4.2.4 Topic Areas

The topics analyzed in the microgrid study are (a) subject areas and (b) author's keywords. The results are answers to the above mentioned RQ on the topic areas and themes in microgrid literature.

Table 4: Top 20 most productive source titles for microgrid research

Source Title	TP	%	TC	NC P	h	g	m	PYS
Renewable and Sustainable Energy Reviews	25	1.82	19	23	1.73	3330	23	2014
Energies	61	4.43	18	32	1.5	1166	61	2013
IEEE Excess	39	2.83	18	32	2	2218	38	2016
Applied Energy	26	1.89	17	25	1.55	1977	25	2014
IEEE Transactions on Smart Grid	10	0.73	11	14	0.85	1116	14	2012
Journal of Energy Storage	16	1.16	11	16	1.83	907	16	2019
Energy	13	0.94	10	13	0.91	594	13	2014
Electric Power System Research	9	0.65	7	8	0.78	272	8	2016
International Journal of Elec Power and Energy Systems	9	0.65	7	8	0.7	184	8	2015
Proceedings of IEEE	7	0.51	7	7	0.5	531	7	2011
Renewable Energy	9	0.65	7	8	0.58	494	8	2013
Sustainability (Switzerland)	17	1.2	7	11	1	152	17	2018
Electronics (Switzerland)	10	0.73	6	9	0.88	90	10	2018
Energy Conversion and Management	6	0.74	6	6	0.55	569	6	2014
Energy Reports	14	1.02	6	10	1.5	109	14	2021
IEEE Transactions on In-dustrial Electronics	6	0.44	6	6	0.46	212	6	2012
IEEE Transactions on Industrial Applications	9	0.65	6	8	0.46	243	8	2012
International Journal of Hydrogen Energy	9	0.65	6	8	0.55	264	8	2014
Asia-Pacific Power and Engineering Conference (APPEEC)	9	0.65	5	6	0.31	43	9	2009

4.2.3 Subject area

This study identifies documents based on their field of study and the source titles under which they have been published. The results are presented in Table 5 below. Microgrid research has emerged in a variety of areas of study. The majority of microgrid research are published in the journal Engineering category, with 1017 documents (31.59%), Energy with 808 documents (25,10%), Computer Science (514; 15.97%), and Mathematics (294; 9.13%). The results also show that the study on microgrids has been published in the journal categorized under other subject areas such as decision science, environmental science, and many others.

Table 5: Subject areas

Subject Area	Number of Documents	%
Engineering	101700	31.59
Energy	80800	25.10
Computer Science	51400	15.97
Mathematics	29400	9.13
Environmental Science	10500	3.26
Physics and Astronomy	10300	3.20
Materials Science	9100	2.83
Decision Sciences	7900	2.45
Social Sciences	6600	2.05
Business, Management and Accounting	3400	1.06
Earth and Planetary Sciences	2400	0.75
Medicine	2000	0.62
Chemical Engineering	1700	0.53
Multidisciplinary	1500	0.47
Chemistry	1200	0.37
Economics, Econometrics and Finance	1100	0.34
Biochemistry, Genetics and Molecular Biology	300	0.09
Neuroscience	200	0.06
Agricultural and Biological Sciences	200	0.06
Nursing	100	0.03
Immunology and Microbiology	100	0.03

4.2.4 Keyword Analysis

Figure 3 shows the top 10 themes related to overall occurrences. The terms” microgrid”,” microgrid”,” electric power networks”,” renewable energy resources”,” smart power grids, ”energy storage”, ”smart grid”, ”energy management” and ”renewable energy” are the most relevant words that were generated.

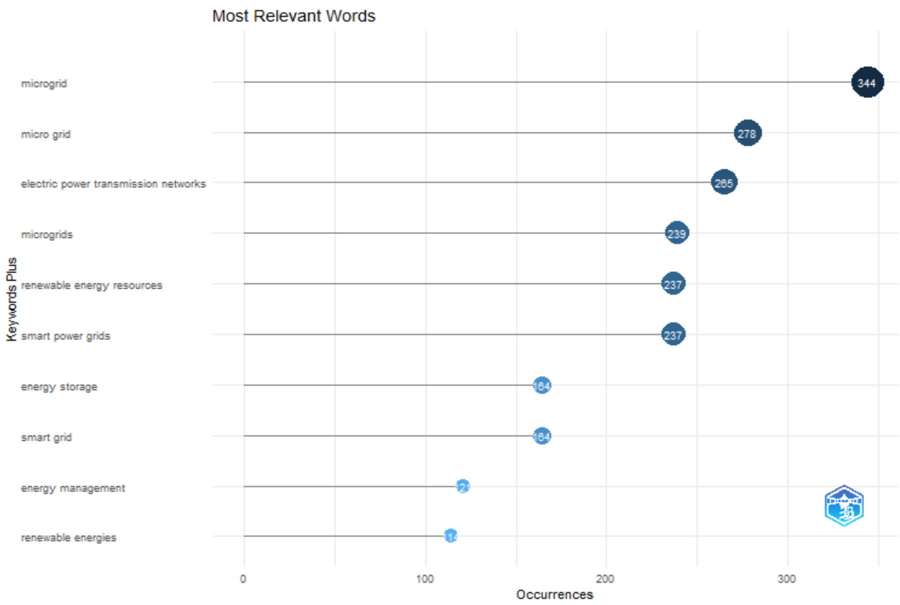

Figure 3: Most relevant research title in microgrid systems from 2002 to 2023

A word cloud is a visual depiction of words based on their frequency and importance [22]. Figure 4 below displays the most internationally representative keywords connected to the microgrid system topic as represented by a word cloud. The most commonly used keywords in microgrid system areas are" microgrid", "electric power networks"," renewable energy resources"," smart power grids," energy storage"," smart grid", "energy management" and "renewable energy".

Figure 4: Scopus's microgrid systems keywords from 2002 to 2023

Figure 5 below, shows the frequency charts top microgrid system keyword growth from 2002 to 2024.

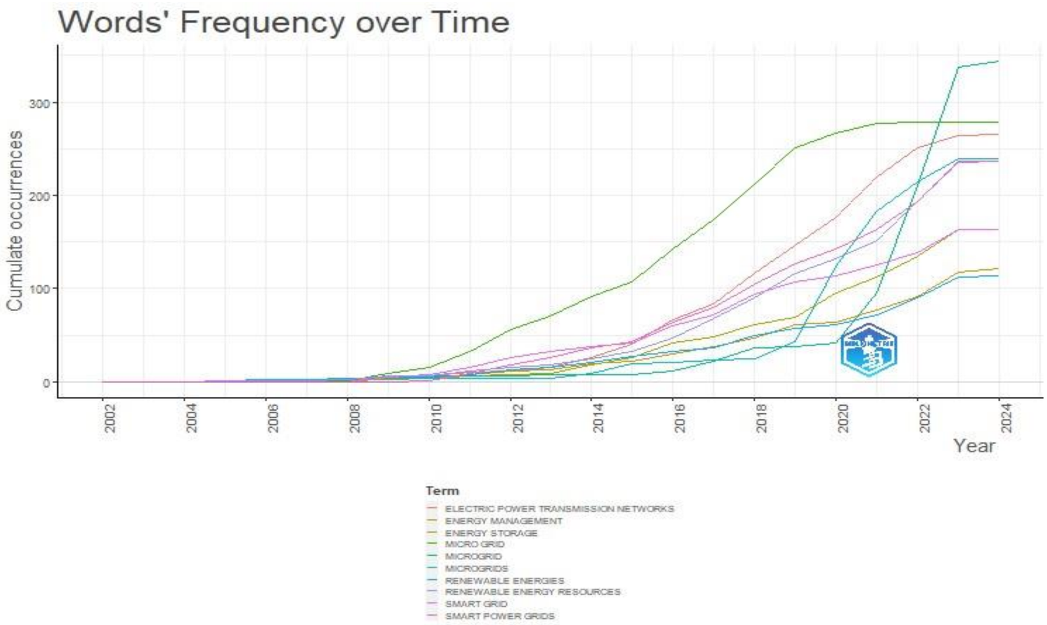

Figure 5: Word growth in microgrid system from 2002 to 2024

Figure 6 below depicts a network visualization map of title and abstract co-occurrence combinations in the microgrid system study domain, as shown in the simulation results below. The objects (circles) represent frequently used terms. The item's weight defines its size (label, ring, or frame). An item's weight (importance) increases as its circle or structure grows larger. The elements' links are represented by the lines connecting them (keywords) [23].

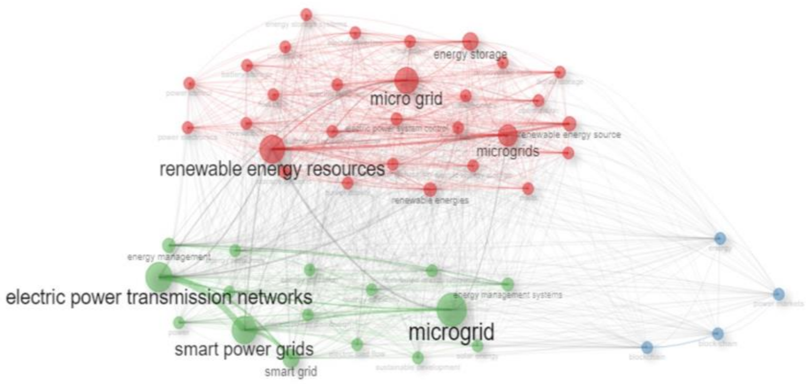

Figure 6: Network visualization map of author keywords with at least three occurrences

4.2.5 Most Productive Contributors in Microgrid Studies

To answer the RQ on the top contributors in microgrid studies, the productive (a) authors, (b) institutions, and (c) countries that contributed the most publications on microgrids from 2002 until 2023 were analyzed. Based on Table 6, researchers from China have dominated the productivity in the microgrid literature. However, Guerrero JM from Spain and Blaabjerg F from Spain, and Blaabjerg F from Denmark are the leading authors. This finding also confirms the previous studies by Tambunan et. Al [13]. Based on this fact, there is an opportunity for researchers from African countries to collaborate so that microgrid research can be extended.

Table 6: Most productive authors with a minimum of five publications

Element	h_index	g_index	m_index	TC	NP	PY_start
GUERRERO JM	13	20	0,92857143	725	20	2011
BLAABJERG F	9	10	0,64285714	3773	10	2011
LI Z	8	16	0,57142857	387	16	2011
VASQUEZ JC	8	12	0,88888889	521	12	2016
WANG J	8	19	0,61538462	546	19	2012
BANSAL RC	7	12	0,875	695	12	2017
SHAHIDEHPOUR M	7	9	0,53846154	802	9	2012
WANG Y	7	14	0,5	293	14	2011
ADEFARATI T	6	10	0,75	523	10	2017
MARNAY C	6	6	0,33333333	2933	6	2007
MENG L	6	7	0,66666667	407	7	2016
WANG X	6	8	0,75	68	12	2017
ZHANG Y	6	12	0,85714286	148	14	2018
JIN Z	5	5	0,55555556	366	5	2016
KHODAEI A	5	5	0,625	368	5	2017
STADLER M	5	5	0,27777778	463	5	2007
ZHANG Z	5	9	0,33333333	88	14	2010
ZHAO Y	5	7	0,33333333	136	7	2010
CHEN J	4	6	0,57142857	102	6	2018
CHUB A	4	5	0,57142857	63	5	2018

4.2.6 Most Productive Institutions

Table 7 shows the top 10 institutions that have contributed the most microgrid research documents. The interesting thing shown in Table 7 is that the production of microgrid literature comes from institutions in China, Denmark, Singapore and Malaysia. Of these top documents, 153 documents (64.03%) came from five Institutions located in China. While 38 documents (15.90%) came from Aalborg University in Denmark, 29 documents (12.13%) from Singapore, and 19 (7,95%) from Malaysia.

Table:7 Top 10 institutions contributing to the publications of microgrid literature

Affiliation	Country	Articles	Percentage %
North China Electric Power University	China	60	20,76
Aalborg University	Denmark	38	13,15
Not Reported	Not Reported	32	11,07
Tianjin University	China	30	10,38
NanyangTechnological University	Singapore	29	10,03
Shandong University	China	25	8,65
Universiti Tenaga Nasional	Malaysia	21	7,27
Huazhong University Of Science And Technology	China	19	6,57
Zhejiang University	China	19	6,57
Department Of Electrical Engineering	Not Reported	16	5,54

4.2.7 Most Productive Countries

The countries that contributed the most to microgrid research from 2002 to 2023 are shown in Table 8. Interestingly, the largest contribution came from countries in the Southeast Asia region, namely China's 189 (13.30%) documents and India's 100 (7,27%) documents. The United States became the third-largest contributor with 86 documents (6.25%). The rest of the countries, such as Italy, the United Kingdom, Spain, Malaysia, Australia, South Africa, Canada, Iran, and Korea, published between 14 to 24 documents related to microgrid. Although countries in the Asian region still dominate the distribution of microgrid research, countries' contribution in the European and American regions has shown an increase. These results also indicate that the topic of microgrid has become a field of interest not just from Asian and European countries but also from Africa.

Table: 8 Countries that contributed to the microgrid publications

Country	**Articles**	**Percentage%**
CHINA	183	13,30
INDIA	100	7,27
USA	86	6,25
ITALY	24	1,74
UNITED KINGDOM	21	1,53
SPAIN	20	1,45
MALAYSIA	19	1,38
AUSTRALIA	17	1,24
SOUTH AFRICA	16	1,16
CANADA	15	1,09
IRAN	15	1,09
KOREA	14	1,02
GERMANY	13	0,94
BRAZIL	11	0,80
DENMARK	11	0,80
FRANCE	10	0,73
PORTUGAL	9	0,65

4.2.8 Collaboration Patterns

This study also provides a network visualization of co-author mapping among different authors (see Figure 7 below). This map employs a fractional counting approach and is based on information from writers who have written at least one microgrid-related document. The intensity of the association between writers is shown by the color, circle size, text size, and thickness of connecting lines. Related writers are usually listed together, as indicated by the same colour. For example, the diagram shows that Guerrero J.M., Jian Z, Meng L, Savaghebi M and Vasquez J.C. collaborate closely. From the analysis of Guerrero J..M, it appears that he has had a cooperation with various writers from various countries.

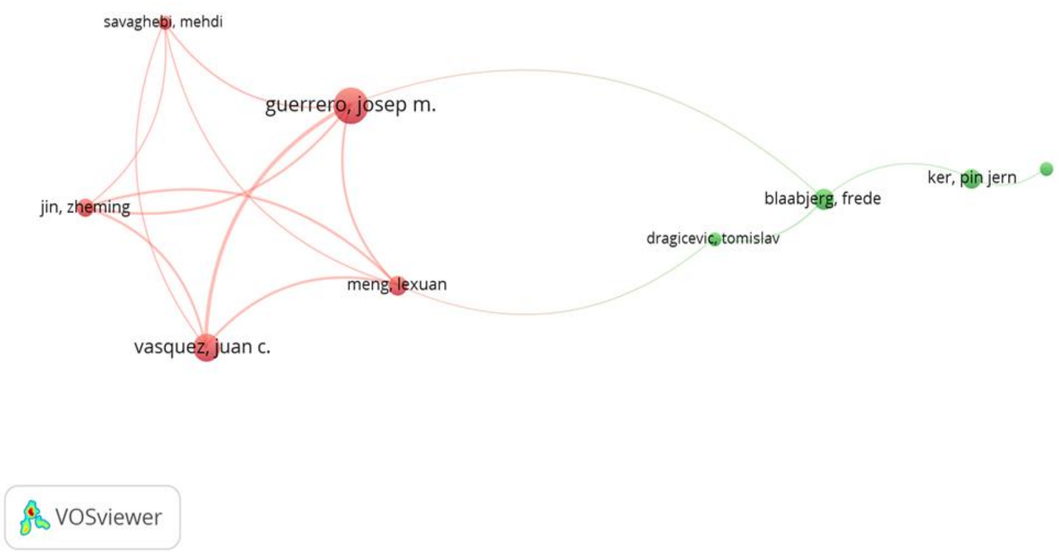

Figure 7: Network visualization map of co-authorship among authors

The next, Figure 8 shows a map of the collaboration network based on their affiliated countries. All countries with a minimum of one document regardless of the number of citations are shown. A network visualization map as per Figure 8 is generated based on the fractional counting method. The map shows three main clusters that exist. Some of the countries' names are not seen on the map, it, for example, in cluster one (Yellow), China has a strong relationship with countries such as Australia, Malaysia, Qatar and Taiwan.

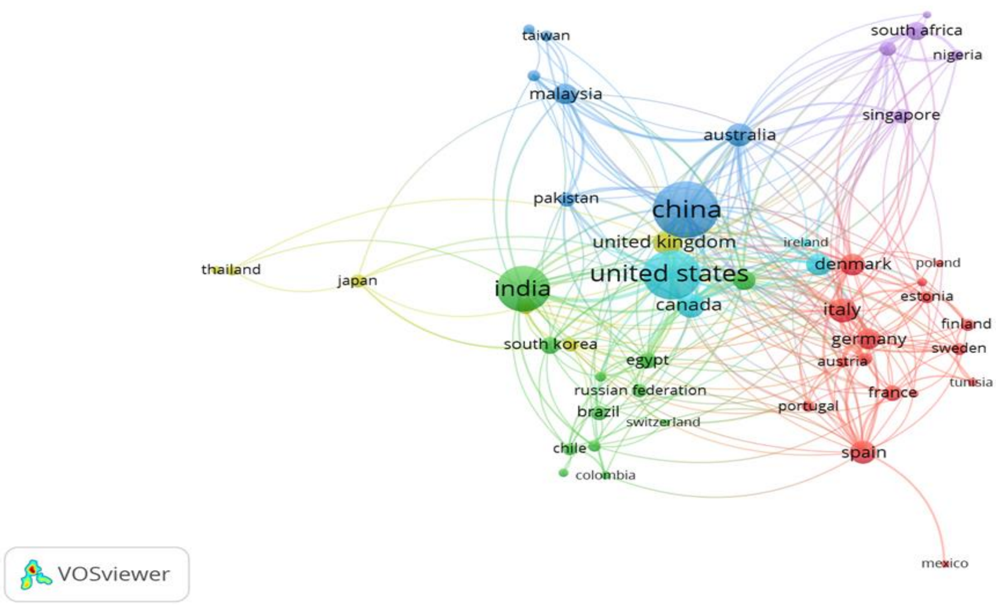

Figure 8: Network visualization map of co-authorship among countries

4.2.9 Most Influential Documents

Table 9 presented the 20 most influential documents within the realm of microgrid research, as determined by their respective citation counts. The two most frequently cited documents are the study of microgrid conducted by Rocabert et al [1] with the title "Control of Power Converters in AC Microgrids". This study is the most cited document considering that it is the first published study of microgrid. Other widely cited documents are reviews on Microgrids (Hatziargyriou N [23]), and Microgrids: A review of technologies, key drivers, and outstanding issues (Hirsch et al [11]).

Table 9: Top 20 highly cited documents

Paper	**Total Citations**	**TC per Year**
ROCABERT J, 2012, IEEE TRANS POWER ELECTRON	2807	215,92
HATZIARGYRIOU N, 2007, IEEE POWER ENERG MAG	2422	134,56
HIRSCH A, 2018, RENEWABLE SUSTAINABLE ENERGY REV	931	133,00
PIAGI P, 2006, IEEE POWER ENG SOC GEN MEET	768	40,42
SAAD W, 2012, IEEE SIGNAL PROCESS MAG	716	55,08
SIMPSON-PORCO JW, 2013, AUTOMATICA	664	55,33
ZIA MF, 2018, APPL ENERGY	650	92,86
PIPATTANASOMPORN M, 2009, IEEE/PES POWER SYST CONF EXPO, PSCE	579	36,19
ZHOU K, 2016, RENEWABLE SUSTAINABLE ENERGY REV	560	62,22
KUMAR D, 2017, IEEE ACCESS	530	66,25
KABALCI Y, 2016, RENEWABLE SUSTAINABLE ENERGY REV	456	50,67
FAISAL M, 2018, IEEE ACCESS	421	60,14
HAJIAGHASI S, 2019, J ENERGY STORAGE	351	58,50
MARNAY C, 2008, IEEE TRANS POWER SYST	327	19,24
ADEFARATI T, 2019, APPL ENERGY	305	50,83
ARANI AAK, 2017, RENEWABLE SUSTAINABLE ENERGY REV	288	36,00
EL-HAWARY ME, 2014, ELECTR POWER COMP SYST	284	25,82
HOSSAIN E, 2014, ENERGY CONVERS MANAGE	279	25,36
SIANO P, 2019, IEEE SYST J	275	45,83
JIN Z, 2016, IEEE ELECTRIF MAG	275	30,56

V. FUTURE WORK AND LIMITATIONS

The study's limitations are mostly due to its reliance on the Scopus database, which could inadvertently leave out significant articles from different sources like Web of Science or IEEE Xplore. Furthermore, the exclusive focus on documents published in English may inadvertently neglect substantial scholarly contributions presented in other languages. Despite the advantages of the bibliometric methodology featured in this analysis for recognizing trends, it lacks a detailed scrutiny of the technical issues or the performance of microgrid projects. Additionally, while the study of blockchain technology in microgrids is conducted in a broad context, it does not tackle distinct challenges like scalability, security, and regulatory structures.

Subsequent research endeavors should broaden their scope to encompass a variety of databases and publications in languages other than English. A more comprehensive inquiry into the technical and regulatory challenges posed by blockchain technology in the context of microgrids is imperative. Moreover, the examination of empirical case studies regarding the application of artificial intelligence and machine learning within microgrids could yield more profound insights into the optimization of operational processes.

VI. Conclusion

In conclusion, microgrid systems have captured considerable interest within the realm of electrical power systems because of their advanced efficiency and adaptability. The present investigation employed bibliometric techniques to pinpoint primary research themes, focal points, and key figures within the realm of microgrid studies. The field of microgrid research has undergone substantial expansion in recent years, emphasizing control methodologies, grid incorporation strategies, and power administration techniques. China has emerged as the primary contributor to microgrid research, followed by Denmark, Singapore, and Malaysia. The analysis of keywords found that subjects such as renewable energy resources, smart grids, energy storage, and energy management are quite important in microgrid study. This study provides researchers and industry experts with significant insights on the current status of microgrid technology and opportunities for future research and development.

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