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Research Article

Condition Monitoring of Stator Winding Insulation in Rotating Electrical Machines: A Bibliometric and Comprehensive Analysis

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Abstract

Rotating electrical machines, as the basic components of modern industrial systems, play a critical role in the production and utilization of electrical energy. The reliability and efficiency of these machines largely depend on the condition of the stator winding insulation. Therefore, effective monitoring and evaluation of the stator winding insulation is of vital importance for the reliable and efficient operation of rotating electrical machines. This study presents a comprehensive bibliometric and conceptual analysis of conventional electrical test methods used in stator winding insulation condition monitoring methods in rotating electrical machines. The bibliometric analysis is performed using data obtained from the Web of Science (WoS) database. In this context, VOSviewer software is used to visualize the publication trends, citation patterns, collaboration networks and key concept relationships in the research area. In addition, this study contributes to a more accurate and comprehensive assessment of the stator winding insulation condition by systematically examining all relevant stator winding insulation condition monitoring methods. In this study, a comprehensive bibliometric analysis was performed to examine the scientific literature on the condition monitoring of stator winding insulation in rotating electrical machines. Data related to 111 publications identified on the Web of Science (WoS) platform were extracted into a text file for the purpose of performing the bibliometric analysis. As a result of the review, it was determined that in addition to traditional offline tests, partial discharge tests and versatile condition monitoring methods can provide more reliable results.

Keywords: Rotating Electric Machines, Stator Winding Insulation, Insulation, Bibliometrics

Döner Elektrik Makinelerinde Stator Sargı Yalıtımı Durum İzleme: Bibliyometrik ve Karşılaştırmalı Bir Analiz

Öz

Modern endüstriyel sistemlerin temel bileşenleri olan döner elektrik makineleri, elektrik enerjisinin üretimi ve kullanımında kritik bir rol oynamaktadır. Bu makinelerin güvenilirliği ve verimliliği büyük ölçüde stator sargı yalıtımının durumuna bağlıdır. Bu nedenle, dönen elektrik makinelerinin güvenilir ve verimli çalışması için stator sargı yalıtımının etkili bir şekilde izlenmesi ve değerlendirilmesi hayati önem taşımaktadır. Bu çalışmada, döner elektrik makinelerinde stator sargı izolasyon durumu izleme yöntemlerinde kullanılan geleneksel elektriksel test yöntemlerinin kapsamlı bir bibliyometrik ve kavramsal analizi sunulmaktadır. Bibliyometrik analiz, Web of Science (WoS) veri tabanından elde edilen veriler kullanılarak gerçekleştirilmiştir. Bu bağlamda, araştırma alanındaki yayın eğilimlerini, atıf modellerini, iş birliği ağlarını ve temel kavram ilişkilerini görselleştirmek için VOSviewer yazılımı kullanılmıştır. Ayrıca bu çalışma, ilgili tüm stator sargısı yalıtım durumu izleme yöntemlerini sistematik olarak inceleyerek stator sargısı yalıtım durumunun daha doğru ve kapsamlı bir şekilde değerlendirilmesine katkıda bulunmaktadır. Bu çalışmada, dönen elektrik makinelerinde stator sargı yalıtımının durum izlemesine ilişkin bilimsel literatürü incelemek amacıyla kapsamlı bir bibliyometrik analiz gerçekleştirilmiştir. Bibliyometrik analizin yapılabilmesi amacıyla Web of Science (WoS) platformunda belirlenen 111 yayına ait veriler metin dosyasına aktarılmıştır. Yapılan inceleme sonucunda, geleneksel çevrimdışı testlere ek olarak kısmi deşarj testleri ve çok yönlü durum izleme yöntemlerinin daha güvenilir sonuçlar verebileceği belirlenmiştir.

Anahtar Kelimeler: Döner Elektrik Makineleri, Stator Sargı Yalıtımı, Yalıtım, Bibliometri

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1. Introduction

Rotating electrical machines constitute one of the fundamental building blocks of modern engineering in terms of the production of electrical energy and its use in industrial systems. In order to extend the life of the machines used in industry and power plants, monitoring the condition of the equipment is also of great importance in this sense [1]. Today's industrial world is built on electrical machines and their advanced control strategies. Industrial processes, due to their highly competitive nature, cannot tolerate any interruption or slowdown. Therefore, condition monitoring and performance evaluation are of vital importance [2].

Insulation is the most sensitive element of electrical machines; it is relatively easily damaged by mechanical effects, environmental influences, oil and dust entering the motor. In this regard, great importance is given to monitoring the insulation condition of windings during the operation of electrical machines [3]. In the literature, two large surveys on asynchronous machine failures were conducted by organizations such as IEEE and EPRI. As a result of these surveys, the largest sources of failures are bearing systems with a rate of 40%, and winding failures with a rate of 30% [2].

The aging of stator insulation of rotating electric machines is affected by: temperature, voltage imbalances (overvoltages), mechanical stresses and ambient conditions. The most common forms of ambient effects are humidity (humidity in the environment, condensation, water vapor, etc.), chemically aggressive media (dissolved salts and acids), dust (metal or coal) and radioactive radiation [4]. Insulation systems deteriorate over time due to factors such as environmental conditions (humidity, temperature, and dust), electrical stress, thermal cycles and mechanical vibration. These deteriorations can cause insulation punctures, arcing and sudden failures, especially in high-voltage systems. Therefore, monitoring the condition of stator insulation systems is becoming increasingly important within the scope of predictive maintenance applications. Predictive maintenance applications require diagnostic tools to determine when insulation aging has occurred and determine the maintenance schedule to prevent sudden failures [5].

This study aims to examine the literature on stator winding insulation monitoring in rotating electric machines with a comprehensive bibliometric analysis and to present the developments in the field at a comparative level. In the existing literature, many studies focus on specific test methods, machine types or fault types; however, a holistic mapping of these studies is limited. Although there are numerous experimental and modeling-based studies in the literature on stator winding insulation in rotating electric machines, a comprehensive bibliometric analysis has not yet been conducted to systematically map the scientific production in this field within a holistic framework. This study aims to fill this gap and analyze the research literature on stator winding insulation monitoring methods both bibliometrically and comparatively. Thus, it is aimed to provide a guiding framework for both the academic community and the practicing engineering community by determining the intellectual structure of the field, leading themes and sub-fields with development potential. In addition, this study analyzes the traditional electrical test methods in the field of stator insulation monitoring in the literature and reveals the most influential authors, themes, publication trends and research gaps, thus aiming to contribute to both the academic literature and create a roadmap for industrial applications.

2. Material and Methods

Condition monitoring electrical test methods are the most frequently studied technical applications in the literature for stator winding insulation condition monitoring. Bibliometric analysis is a research methodology that reveals research trends, interactions and development dynamics in a certain field by examining scientific publications with quantitative and statistical methods [6]. This method allows to determine the intellectual structure of a research field, key topics, leading authors, institutions and countries through analysis of large data sets. Bibliometric analysis is a powerful tool for detecting gaps in the literature, determining future research directions and understanding the evolution of scientific knowledge [7].

In this study, a comprehensive bibliometric analysis was performed to examine the scientific literature on the condition monitoring of stator winding insulation in rotating electrical machines. Web of Science (WoS) Core Collection database was used for the analysis. The search strategy was created by combining the relevant keywords with Boolean operators. The keywords used are: "rotating machine", "electrical machine", "stator winding", "insulation", "condition monitoring", "condition assessment", "diagnosis", "prognosis", "fault detection", "aging", "degradation". The search query related to these keywords was created as follows:

(("rotating machine" OR "electrical machine") AND ("stator winding" OR "insulation") AND ("condition monitoring" OR "condition assessment" OR "diagnosis" OR "prognosis" OR "fault detection" OR "aging" OR "degradation"))

The search results are limited to "Article" and "Review Article" as publication types. Additionally, filtering was done on related fields (e.g. "Engineering, Electrical & Electronic", "Energy & Fuels", "Physics Applied", "Engineering Multidisciplinary", "Engineering Mechanical"). No filtering was applied as of publication date, and search results made on 10.06.2025 were taken into account.

For the bibliometric analysis, a text file was obtained from the Web of Science database in the "tab delimited file, full records, and cited references" format. Furthermore, "Publication Years" and "WoS Categories / Publication field" analyses were also taken from the WOS database for the relevant publication cluster and used within the publication.

The 111 publications included in the analysis allowed for a more focused assessment of the specific research area. A cluster of 111 publications is considered sufficient to clearly demonstrate the key trends, influential studies, leading authors, and conceptual relationships related to this specific research area.

Effective winding insulation in electric machines provides electrical isolation by preventing conduction in adjacent motor windings [8]. Electrical test methods applied to monitor the condition of the stator winding insulation system play a critical role in ensuring the reliability and continuity of rotating electric machines. These methods generally consist of measurements that evaluate the dielectric properties of the insulation and are applied both in periodic field maintenance processes and within the scope of condition monitoring systems.

The primary goal of this study is to visualize the current structure of the relevant literature, its leading authors, its conceptual map, and its research trends. VosViewer was chosen for its application due to its advantages such as visualization and mapping capabilities, conceptual clustering and analysis capabilities (such as co-accuracy and clustering), user-friendly interface, and accessibility.

2.1. Standard Winding Insulation Condition Monitoring Tests

The most common method in the industry to determine the condition of winding insulation of electrical machines is based on the development of offline tests, which serve to characterize the health of the insulation system and are aimed at measuring different parameters. These tests are performed not only periodically during planned maintenance stops of the plant, but also during commissioning of the motor or generator [9].

The most common standard offline tests for monitoring insulation condition are as follows; Insulation Resistance (IR) test is an insulation condition test examined in IEEE 43-2000 standards. IEEE Std 43-2000 standard contains IEEE recommended practices for testing the insulation resistance of rotating machinery.

Table 1. Recommended Minimum Insulation Resistance [11]

Minimum insulation resistance in MΩ	**Test specimen**
$IR_{1\ min} = kV + 1$	For most windings made before about 1970, all field windings and others not described below
$IR_{1\ min} = 100$	For most AC windings built after about 1970 (form-wound coils)
$IR_{1\ min} = 5$	For most machines with random-wound stator coils and form-wound coils rated below 1 kV and DC armatures

The recommended minimum insulation resistance values are specified in the standard and are shown in Table 1. The measurement results above these values are among the acceptance conditions of the test [10].

The polarization index test is a technique that adds a time dimension to the insulation resistance measurement. In this test, the ratio of the resistance values obtained at 1 minute and 10 minutes under constant DC voltage applied to the windings is calculated. Insulations in good condition show higher resistance over time due to less surface current and more dielectric absorption.

$$PI = R_{10}/R_{1}. \tag{1}$$

A low PI indicates that a winding may be contaminated with oil, dirt, etc. or moisture. In the polarization index test, a relatively high DC voltage is applied between the winding conductor and the stator or rotor body. The leakage current flowing in the circuit is then measured. In this case, the insulation resistance can be found by applying Ohm's law.

$$R_t = V/I_t \quad (2)$$

The insulation resistance value is calculated by dividing the applied DC test voltage by the current passing through the circuit at the moment “t” [12].

Table 2. Polarization Index for Classification of Insulation Condition [8]

Polarization Index	Diagnosis
PI < 1,0	Dangerous situation
1,0 ≤ PI < 2,0	Bad
2,0 ≤ PI <4,0	Good
PI ≥ 4.0	Perfect

The evaluation criteria for the polarization index values according to the relevant standards are given in Table 2. Here, PI<2.0 indicates that there is a very serious doubt about the insulation.

In the literature, the Power Factor (PF) test represents PF cosφ, while the Dissipation Factor (DF) test represents DF tan δ. It is an indirect way to determine whether Partial Discharge (PD) has occurred in a high voltage stator winding. Since PD (partial discharge) is an indication of many high voltage winding insulation degradation mechanisms, this test can indicate whether many failure processes have occurred. In addition to its use as an offline maintenance test, the methodology and analysis methods of the test have been examined with IEEE 286-2000 and its IEC equivalent IEC 60894 [12]. IEEE 286-2000 standard defines the stages of power factor tip-up tests to determine the deterioration of stator winding insulation of electrical machines.

The power factor test (PF or DF), also known as the tip-up test, is measured at least two voltage levels. The low voltage PF value (PF_{lv}) is an indication of the normal dielectric losses in the insulation. This is usually measured at about 20% of the nominal line-to-earth voltage of the stator winding. The voltage is then increased to the nominal line-to-earth voltage and the test is repeated (PF_{hv}).

$$tip-up = PF_{hv} - PF_{lv} \quad (3)$$

The higher the tip-up value, the more energy is consumed by partial discharge disturbances, which is a sign of a deterioration and aging process on the insulation side [12].

Partial discharge test is known as PD test in the literature. Partial discharge monitoring is one of the most powerful methods to determine the condition of the insulation. Partial discharge (PD) is caused by the formation of small electric sparks in the air-filled cavities inside the insulation wall. Partial discharges (PD) are both a diagnostic symptom and a result of the deterioration and aging of the insulation of rotating electrical machines [13]. They occur when the voltage on the windings exceeds the electrical breakdown/puncture power of the air in the gaps, cavities or gaps in the insulation. Monitoring the PD activity allows the determination of the level of insulation deterioration and even the detection of potential insulation defects [9]. Life models can be created based on the measured quantities obtained from partial discharges and maintenance actions can be planned [14].

Noise is one of the unavoidable factors of PD measurement for both conventional and non-conventional methods. Even though there are many noise-filtering tools in frequency domain, such as three center frequencies of relation diagram, multi-channel synchronous of PD measurement, and time resolved partial discharge (TRPD), there are many challenging to extract waveform characteristics of PD pulses [15, 16]. To overcome those difficulties, recently several methods have been studied that can analyze and generate signal on time-frequency domain such as wavelet transformation (WT) or other methods. However, only the WT approach is insufficient to denoise a nonstationary and nonlinear PD signal. Although these methods achieve certain results in removing noise from the signal, there are still many problems such that it is difficult and confusing to choose wavelet basis functions, wavelet thresholds, decomposition levels, and so on since it depends largely on human experience [17].

Basically, the standard PD (Partial Discharge) test, as mentioned in IEC 60034-27 standards, consists of installing a series of coupling capacitors across the terminals of the electrical machine and monitoring the high frequency currents flowing through these capacitors in case of partial discharge in the insulation. This test can be performed in online or offline mode [18].

Finally, there are some additional tests that are a subject of some controversy because they are considered destructive by many users. These are the High voltage (HiPot) tests and the Impulse Voltage (surge) tests, which are generally pass/fail tests. HiPot tests aim to evaluate the electrical integrity of the insulation and to detect possible structural damage. Basically, they aim to prove that the insulation wall system can withstand a high applied voltage without exhibiting an exceptionally high leakage current. There are several variants depending on whether the test can be stopped before the insulation collapses (conventional and controlled overvoltage tests). The HiPot step voltage is the most common; in this test, the applied test voltage is increased in a series of steps until it reaches the maximum value defined by the Standard. On the other hand, the Surge test is used to find insulation weakness between the strands. It consists of applying a high current pulse with a rapid rise time to a winding. This will cause a voltage difference between adjacent wire loops within the winding. If the insulation between two loops of conductor is damaged or weakened in some way and the voltage difference between the wires is high enough, an arc will occur between the wires. This arc will show up as a change in the surge waveform monitored by the surge tester [9].

3. Results and Discussion

3.1. Bibliometric Analysis Results

A total of 111 publication contents were found on the Web of Science (WoS) platform used in the bibliometric analysis. The data of the selected 111 contents (with information such as keywords, citations, authors, links, published journals, etc.) were extracted into a text file (tab delimited file, full records and cited references) to perform the bibliometric analysis. Bibliometric analysis was performed using a third-party open-source software such as VOSviewer software.

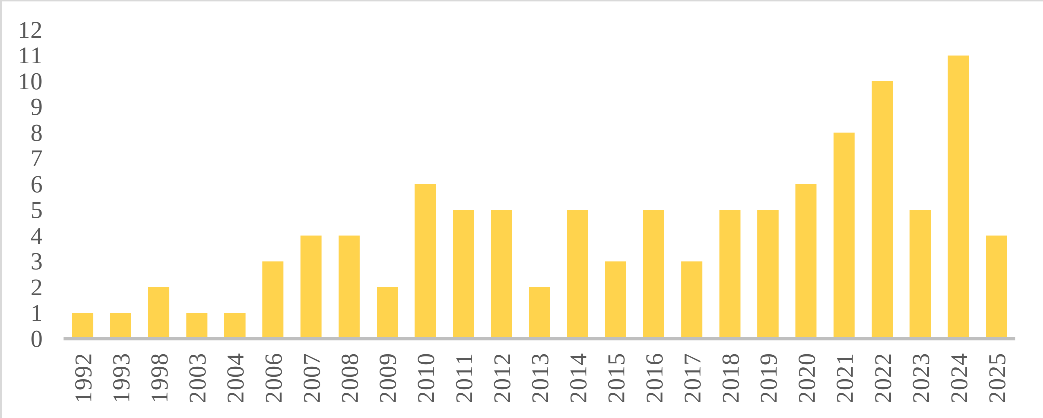

Figure 1. Graph of Academic Publications Published in Related Fields by Years Taken from Web of Science

As a result of the analysis made on the basis of publication date on the Web of Science database, a graph showing the development of academic publications in this field over the years is shown in Figure 1. It is seen that there has been an increase in academic publications written in this field after 2010. It has been evaluated that this situation may be due to the industry 4.0 applications first introduced in 2011 at the Hannover Trade Fair [19]. In addition, with the acceptance of condition monitoring methods throughout the industry, the subject has become important and popular in many educational institutions. Therefore, a large number of articles have been published over time, which reveals the fact that the popularity and scope of research studies in this field are increasing day by day [20]. Again, it is seen that the years with the most publications in this context are 2022 (10 pieces) and 2024 (11 pieces).

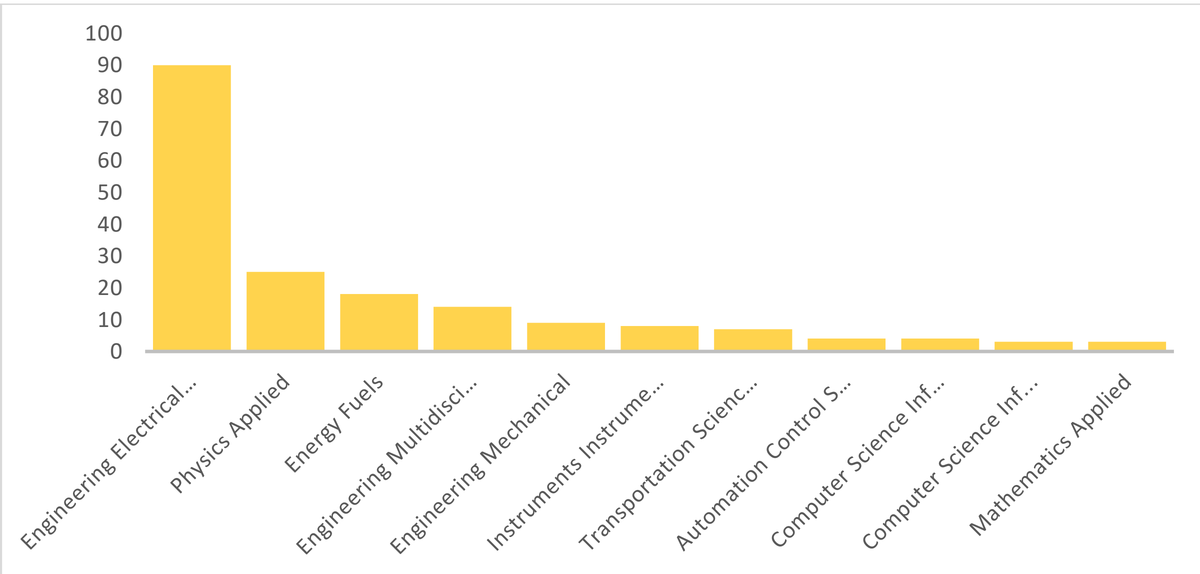

Figure 2. Graph of Academic Publications Published in Related Fields According to WoS Categories Taken from Web of Science

Again, as a result of the analysis made on the basis of categories via the Web of Science (WoS) database, it is seen that the categories with the most publications in this field are; Electrical and

Electronics Engineering (90 items), Applied Physics (25 items), Energy (18 items) and Multidisciplinary Engineering (12 items). Due to the wide range of usage areas of electrical machines, it is seen that a limited number of publications have been produced in this context in other fields (Figure 2).

Table 3. VOSviewer Software Authors' Publication, Citation and Link Power Table

No	Author Name	Number of Publications	Number of Citations	Total Link Strength
1	Lee, Sang Bin	3	76	16
2	Huang, Xiaoyan	2	7	15
3	Zhang, Jian	2	7	15
4	Zhang, Qin	2	7	15
5	Yang, Jinkyu	2	71	12
6	Li, Hao	2	29	10
7	Xiang, Dawei	2	29	10
8	Fang, Youtong	1	1	8
9	He, Xiangning	1	1	8
10	Li, Hongbo	1	1	8

As a result of the bibliometric analysis conducted via VOSViewer software, the “Co-authorship of authors” filter was first selected. In this section, VOSViewer software detected 169 authors that were suitable for this filter. Accordingly, the top 10 authors according to the number of publications, citation counts and total connection strengths of the authors are given in Table 3.

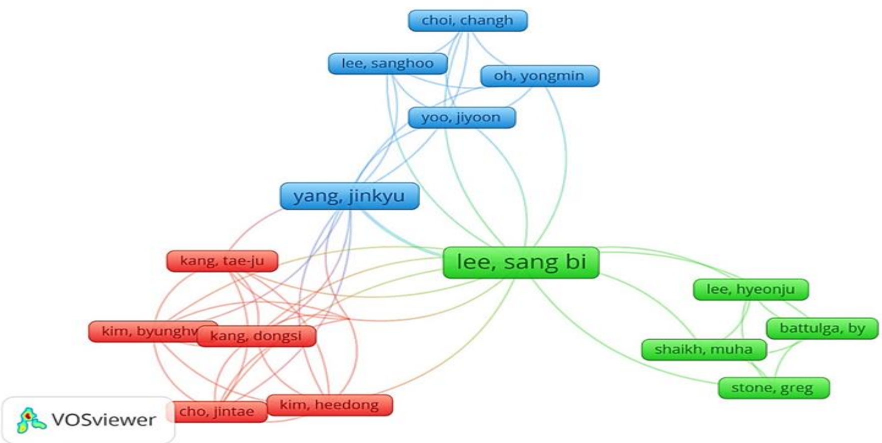

Figure 3. VOSviewer Network Map Display Screen Output (Co-authorship of Authors)

The network mapping was performed by selecting the largest group with the most relationships (16 items). Figure 3 shows the mapping performed by VOSViewer software based on co-authorship status.

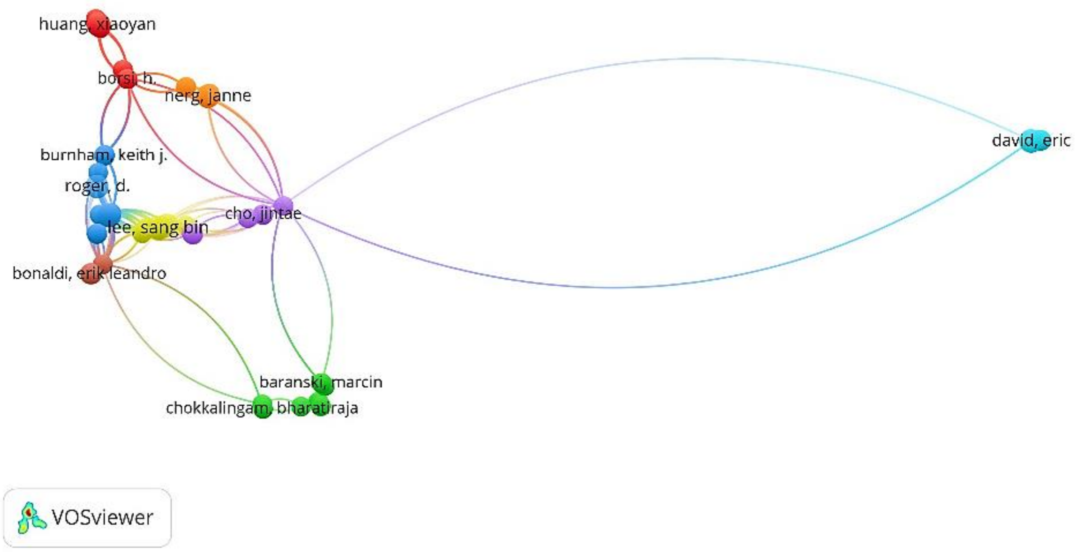

Figure 4. VOSviewer Network Map Display Screen Output (Citation of Authors)

Another analysis method, "Author Citation Analysis," was selected through the VOSviewer software. In this section, the VOSviewer software identified 169 authors who met this filter. A screenshot of the network map showing the author citation analysis is shown in Figure 4.

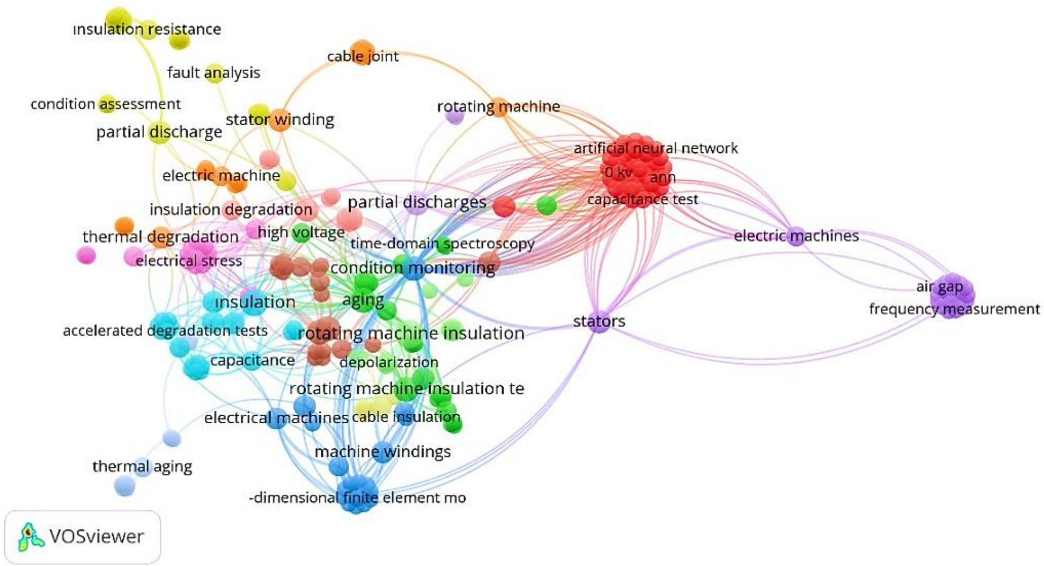

Figure 5. VOSviewer Network Map Display Screen Output (Co occurence of Author Keywords)

The "Keyword Analysis" (Co-occurrence of Author keywords) filter was selected via the VOSviewer software. A screenshot of the network map showing keyword usage is shown in Figure 5. This analysis revealed that the most frequently used keywords were "rotating machine insulation" with 8 matches and "insulation" with 7 matches. As seen in the keyword analysis given in Figure 5, it was observed that the some of authors in the relevant literature also added machine learning methods such as Artificial Neural Networks to the keywords.

Table 4. Publication Numbers and Citation Numbers of Insulation Status Determination Tests by Countries

No	Country	Number of Publications	Number of Citations
1	Canada	7	147
2	India	5	47
3	Peoples R China	5	39
4	France	4	129
5	South Korea	4	76
6	Germany	3	111
7	Australia	3	75
8	Sweden	3	31
9	England	2	50
10	Denmark	2	26

The "Country Analysis" (Co-author of countries) filter was selected using the VOSviewer software. The top 10 countries with the most publications, along with their citation counts, are listed in Table 4. As can be seen, Canada was the country with the most citations and publications, followed by India, China, and France, which also produced publications contributing to the relevant field.

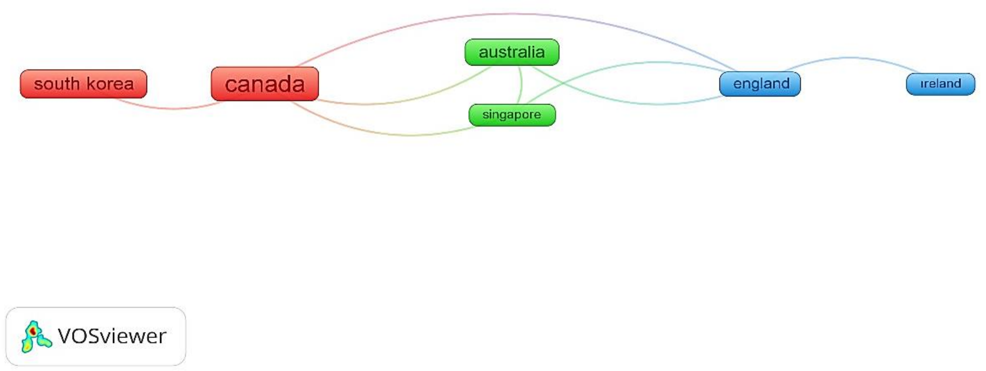

Figure 6. VOSviewer Country Analysis Network Map Display Screen Output (Co-author of Countries)

In this context, a screenshot of the VOSviewer software network map by author's country is shown in Figure 6. This analysis displays the network map for the six most closely related countries, revealing a relationship between publications from Canada, Australia, and the UK. However, less correlation was found between publications from India and China and publications from other countries.

3.2. Comparative Analysis Results

As a result of detailed comparative analyses, advantages and disadvantages of stator winding insulation condition monitoring tests were identified. These tests were categorized as Insulation Resistance and Polarization Index Tests, Capacitance and Tan δ (Dissipation Factor) Tests, and Partial Discharge (PD) Tests.

3.2.1. Results of Insulation Resistance (IR) and Polarization Index (PI) Tests

As a result of the analyses, the primary advantage of these test methods is that insulation resistance measurement is one of the most fundamental and widely used tests in the industry. Its ease of application and ability to be performed in the field with portable devices make it widely used. It provides information about the general condition of the insulation, and low values can indicate problems such as moisture, dust, or surface contamination. Low Polarization Index (PI) values may indicate insulation deterioration due to moisture or contamination. High PI values, on the other hand, indicate that the insulation is dry and clean. PI testing also reflects insulation aging and dielectric absorption characteristics. It is more sensitive than IR testing and is preferred in periodic maintenance programs.

One of the most well-known and identified disadvantages of insulation resistance (IR) and polarization index (PI) testing is that single, one-time IR (insulation resistance) measurements alone may not detect time-dependent deterioration. The information they provide is often based on instantaneous measurement values and lacks continuity. Therefore, these tests need to be supported by continuous monitoring systems. Furthermore, the PI (Polarization Index) test has a time cost, requiring a constant voltage applied throughout the test and a 10-minute wait. It may be insufficient to detect the early stages of insulation deterioration. Using it in conjunction with other tests for a more comprehensive assessment can yield more accurate results.

3.2.2. Results of Capacitance and Tan δ (Dissipation Factor) Tests

The primary advantage of capacitance, PF (Power Factor), and DF (Dissipation Factor) testing methods is that they reveal the insulation system's energy loss characteristics under AC voltage. They have been found to be effective in monitoring both core deterioration in windings and the effects of environmental influences on surface currents. Their integration into online (powered) systems allows for trend analysis.

The primary disadvantage of capacitance, PF (Power Factor), and DF (Dissipation Factor) testing methods is that they require specialized equipment and frequency-controlled AC sources. Furthermore, the sensitivity of these tests can be limited in large-volume generators and motors.

3.2.3. Partial Discharge (PD) Test Results

Analyses indicate that the primary advantage of Partial Discharge (PD) testing is its ability to detect micro-arcing events that do not completely penetrate the insulation system but cause localized deterioration. It can also provide early warning signs of aging, moisture, manufacturing defects, or installation problems. In this context, it provides high sensitivity in detecting defects within the insulation, such as air pockets, contamination, poor interlayer adhesion, or microcracks. It is also useful in uncovering other sources of failure, such as surface contamination and inadequate gaps between phases. This test method allows for online testing, meaning it can be performed while the machine is in operation. Furthermore, the test operator has control over the applied voltage, allowing for the measurement of discharge onset and extinction voltages.

One of the most commonly analyzed disadvantages of Partial Discharge (PD) testing is its greater complexity in terms of application and interpretation compared to other tests. It is particularly susceptible to environmental electrical interference in online testing. Furthermore, some defect mechanisms, such as loose windings, cannot be detected using offline PD testing.

4. Conclusion

This comprehensive assessment, along with a holistic analysis of electrical tests used in stator winding insulation condition monitoring, provides a comprehensive overview of scientific and applied knowledge by illustrating research trends in the field. The findings aim to serve as a literature-based, decision-making reference for both researchers and industrial maintenance professionals.

In this study, a scientific mapping was also made using bibliometric analysis to evaluate the trends in academic publications produced in the relevant literature.

Based on a bibliometric review, it was observed that, in addition to traditional stator winding insulation condition monitoring methods, authors also keyword-based analyses of modern machine learning methods such as artificial neural networks, and publications showed an improvement in this regard. In this regard, some authors have demonstrated that ANNs mimic the cognitive learning processes of the human brain and, unlike classical computational methods, can solve nonlinear problems such as prediction, optimization, recognition, and control [21]. Similarly, some studies emphasized that initially, mathematical and statistical methods were used in predictive maintenance studies to predict failures and perform maintenance accordingly. However, they emphasized that traditional methods proved inadequate due to the increase in data volume, variables, and uncertainties. They also noted that machine learning algorithms with autonomous learning and adaptation capabilities are being used in such failure prediction studies [22].

A look at the growth trend in the number of publications reveals an increase that began in 2010, with further increases in publications in the relevant field over the last five years. This trend indicates the growing academic popularity of the relevant field.

The vast majority of publications focusing on stator winding insulation condition monitoring in rotating electrical machines have been published in the field of Electrical and Electronics Engineering, while studies on this topic also exist in the fields of Applied Physics and Energy. Therefore, the widespread use of electrical machines in the energy sector and the need for predictive maintenance/condition monitoring are believed to be driving the development of publications in this field.

Traditional electrical testing methods for stator winding insulation conditions in rotating electrical machines were also examined, and the advantages and disadvantages of these tests were highlighted. Following this detailed review, it was determined that, in addition to traditional offline tests such as insulation resistance and power factor tests, partial discharge tests and monitoring, as well as multifaceted condition monitoring, could yield more reliable results. Furthermore, it was concluded that combining electrical test measurements with modern approaches such as machine learning and fuzzy logic could offer unique contributions to academia in areas such as trend analysis and lifespan prediction.

Hybrid applications of machine learning methods for stator winding insulation condition monitoring in rotating electric machines could further contribute to the relevant literature in the future. Furthermore, increasing experimental studies on winding insulation condition monitoring tests may confirm modeling studies in this area.

Ethics in Publishing

This research maintains high standards of academic integrity and research ethics at every stage of the bibliometric analysis. These data have been verified against the Web of Science (WoS) Core Collection, a respected and publicly accessible repository. All information regarding bibliometric data extraction, analysis, and interpretation is conducted in accordance with the terms of service and usage policies recorded by WoS. No proprietary or confidential information was extracted or used during the data collection process. The authors acknowledge that these products do not involve human subjects, conduct animal experiments, or require any procedures requiring ethical approval from an institutional review body. However, the principles of objectivity, accuracy, and transparency were adhered to throughout the analysis. The results presented here reflect the interpretation of the bibliometric data, without the disclosure of any conflicts of interest, and without the need for bibliometric storage and storage. This research aims to advance knowledge of stator winding insulation condition monitoring within the scientific community while adhering to the highest ethical values in academic publishing. There are no ethical issues regarding the publication of this study.

Author Contributions:

[1] **M. Cihat Özgenel**: Conceptualization of the study, analysis of results, and drafting of the manuscript.

[2] **Emre Demirel:** Bibliometrics analysis results, literature review and final editing and proofreading of the manuscript.

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