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RELEVANCE OF RESEARCH ON FAILURE TO POWER TRANSFORMERS, REVIEW

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Abstract: This review article examines the current status of the topic by analyzing the scientific papers published in the last fifty years in the IEEE Xplore database related to power transformer faults. In this article, organizations, regions, and publishing houses dealing with power transformer damage are analyzed, and the share of journals and conferences in general publications is given. At the same time, foundations sponsoring scientific research and foreign scientists who wrote dissertations in this field are cited. The IEEE Xplore and Google Scholar databases were used to construct the graphs. Systematic analysis was used to construct charts of published scientific works. Statistical analysis was used to construct a list of organizations that published scientific works related to the topic, to determine the share of journals and conferences in the publications. The results of the analysis showed that the number of publications on the fault of power transformers is continuously increasing from year to year, which indicates that the field is becoming more relevant. Especially in Beijing, many scientific works have been published within the topic. Foundations can be found on all continents. In the future, they can use this article as analyzed data in conducting research on power transformer damage.

Keywords: power transformers, faults, fault analysis, journal paper, conference paper, foundations, analysis organizations, field scientists, IEEE Xplore database.

Introduction. It is not secret that one of the most crucial parts of the power system nowadays is the power transformer. The invention of power transformers made it possible to build modern alternating current power supply systems and to transmit large amounts of electrical energy over long distances. At the same time, power transformers play a major role in reducing the power losses by increasing the voltage.

The growing global population and improved living standards brought about by the advancement of contemporary technology raise consumer demand for energy, necessitating the high load level operating of power transformers. This, in turn, increases the probability of failure of power transformers and shortens the service life [1].

The key to guaranteeing the success of improving reliability of power transformer is understanding the failure mechanisms that the equipment is prone to, their core causes, and, finally, the parameters that must be monitored to ensure that they are discovered before faults or failures occur [2]. Information about the mechanisms of power transformer failures and their causes will help to plan the strategy of the power grid company in the future [3].

In this article, attention is focused on determining the relevance of the topic of power transformer damage in the past and today. The analytical article provides an

analysis of the number of publications published in the IEEE Xplore database within half a century, organizations that have conducted and are conducting research within the topic. Also, the scientists who conducted research within the topic and the foundations that financially supported the research work were outlined.

Methodology. The algorithm of this analytical research work is depicted in Figure 1. First, articles related to the topic of power transformer damage analysis published in 1974-2023 were selected from the IEEE Xplore database. It showed that there are more than 25,000 publications in the database. After that, it was filtered by keywords.



Figure 1. Algorithm for writing an analytical article.

After that, publications were filtered by subject area and by publishing year. Using results of filter, the number of 50-year publications was analyzed by year and placed in a clustered column. In order to find out the weight of the work on the topic in recent years, the number of publications in the last decade was analyzed. The results were entered into a line chart.

In order to determine which organizations are conducting scientific research on the topic analyzed of organizations that conducted research on the analysis of power transformer damage in the IEEE Xplore database in 1974-2023 about filtered publishing. Results were entered in Bar Chart.

Data warehouses such as IEEE Xplore, Google scholar, dissercat, and ProQuest were used to identify scientists who conducted scientific research within the topic and to find fundings.

Results and Discussion. Today, a number of databases containing published scientific research works have been formed, and IEEE Xplore is one of them. Today, it has collected more than 6 million scientific research works. Figure 2 shows the analysis of published scientific research works on the analysis of power transformer damage in the IEEE Xplore database from 1974-2023. In this case, the number of articles published every 5 years is analyzed. From the picture, we can see that the number of publications is continuously increasing.

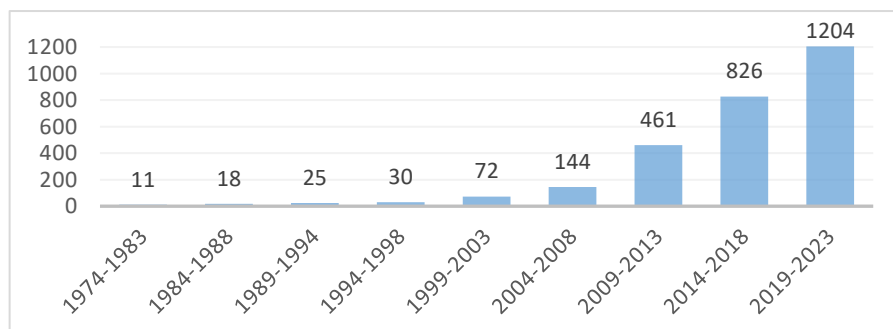


Figure 2. Analysis of published research papers on power transformer damage analysis in the IEEE Xplore database in 1974-2023.

The results of the analysis show that, despite the fact that the number of scientific research publications has increased year by year, until 2008 there were few publications related to this topic. In other words, 10% of the total publications were published during the first 34 years. In the last 5 years, 1204 research papers or 43% of the total articles were published in journals and conferences.

Figure 3 shows the analysis of scientific research papers published in the IEEE Xplore database on the analysis of power transformer damage in 2013-2023. This is a logical continuation of the graph presented in Figure 2. In this decade, 2150 scientific research papers were published in journals and conferences in the IEEE Xplore database.

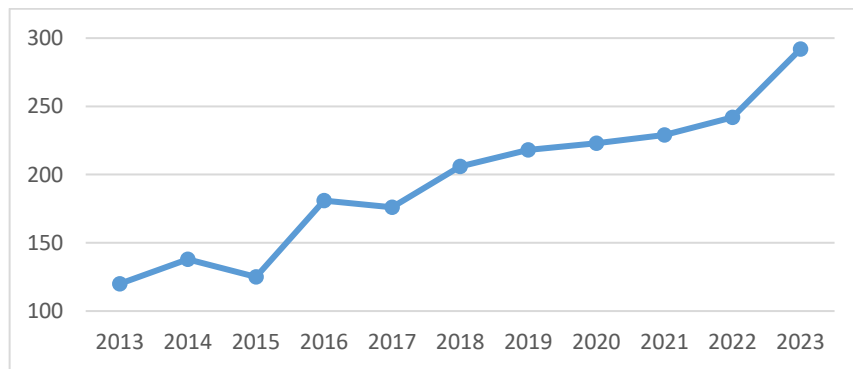


Figure 3. Analysis of scientific research works published in the IEEE Xplore database on the analysis of power transformer damage in 2013-2023.

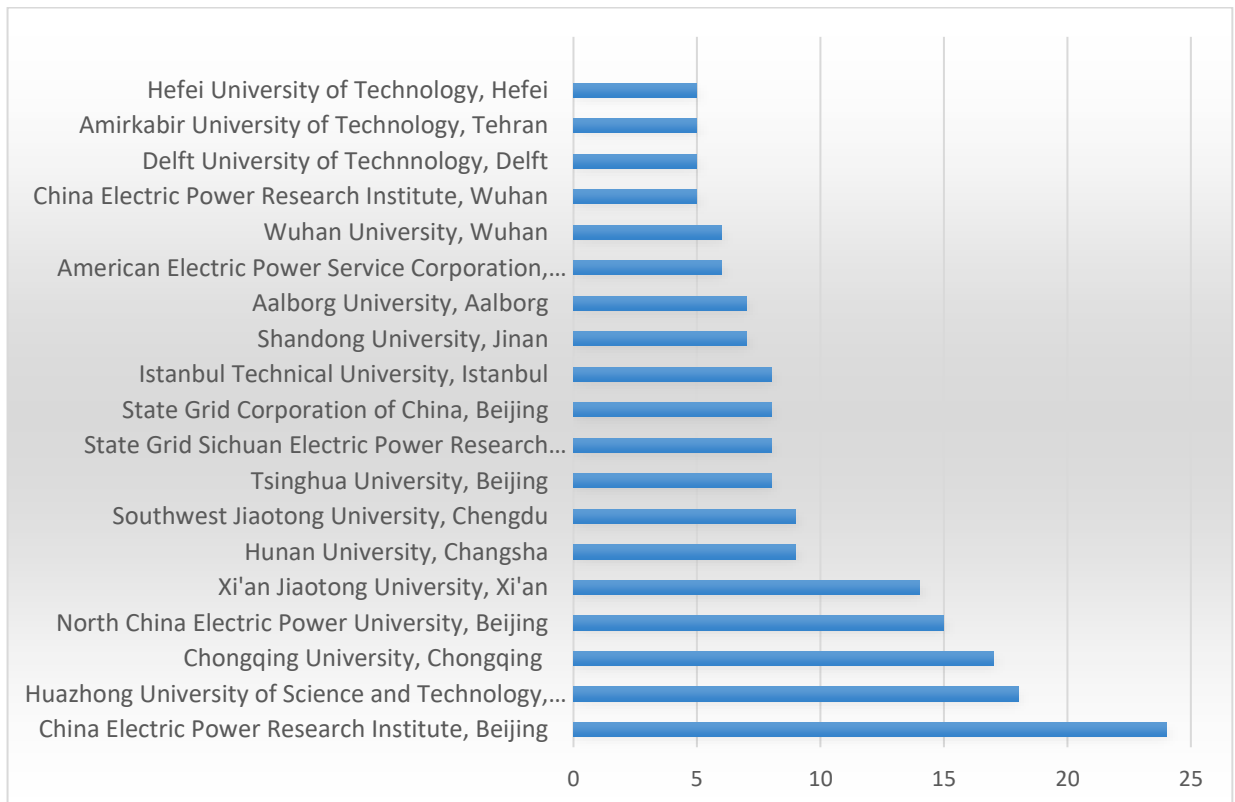


Figure 4. Analysis of organizations that conducted research on the analysis of power transformer damage in the IEEE Xplore database in 1974-2023.

From the graph, we can see that the number of publications decreased in 2015, but continued to grow in the rest of the years. The number of publications of scientific works increased by 1% or 20 articles annually. This indicates that the power transformers, which are the heart of the energy system, have received increasing attention in recent years.

Figure 4 shows the analysis of organizations that conducted scientific research on the analysis of power transformer damage in 1974-2023 in the IEEE Xplore database. Scientific research works are mainly carried out in scientific research institutes and higher education institutions, and we can see that it was also carried out in the Electric Power Service Corporation [4].

As can be seen from the graph, the main part of the conducted scientific research works corresponds to the Beijing province of China. The China Electric Power Research Institute [5] in this capital leads the list of organizations that have published the most on the topic of power transformer damage. The share of this university is 13%.

Figure 5 shows the analysis of journals and conferences in the IEEE Xplore database that published research papers on power transformer damage analysis in 1974-2023.

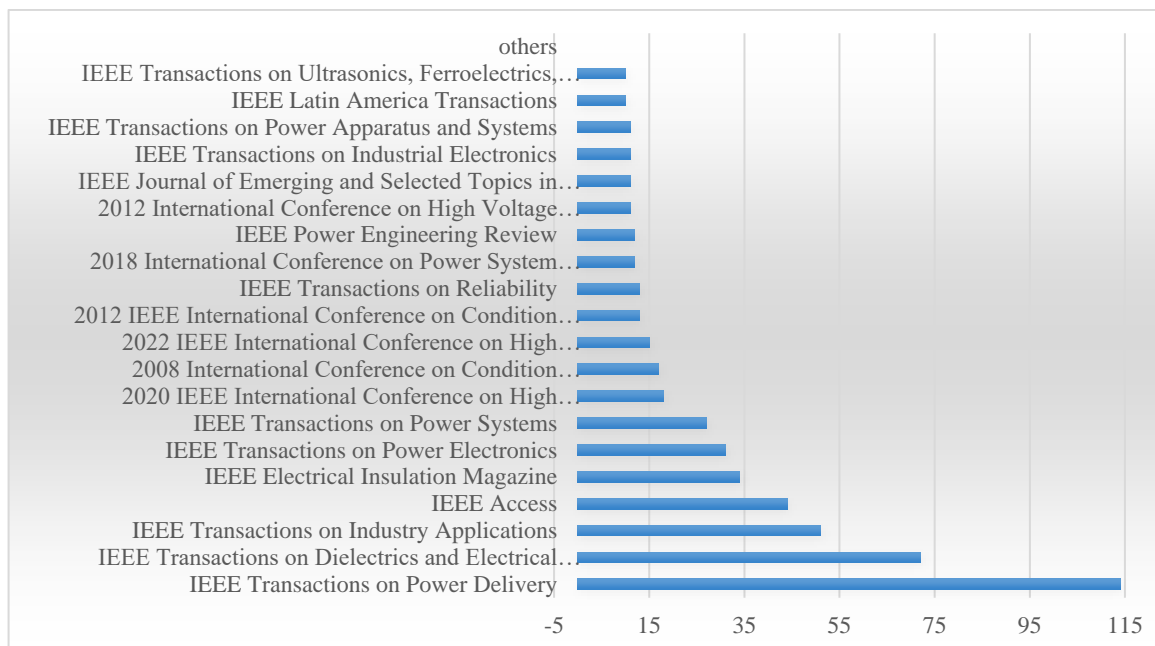


Figure 5. Analysis number of published articles in journals and conferences in the IEEE Xplore database on the analysis of power transformer damage in 1974-2023.

IEEE is the most published publisher, with 2,747 scientific research papers published between 1974 and 2023.

Figure 6 describes the share of journals, conferences, books, standards, magazines, and early access articles in scientific research papers published on the analysis of power transformer damage in the IEEE Xplore database in 1974-2023. In recent years, the number of conferences on the topic of improving the reliability of power transformers has been increasing. Diagnosing and monitoring for power transformers have become a central topic at some conferences [6].

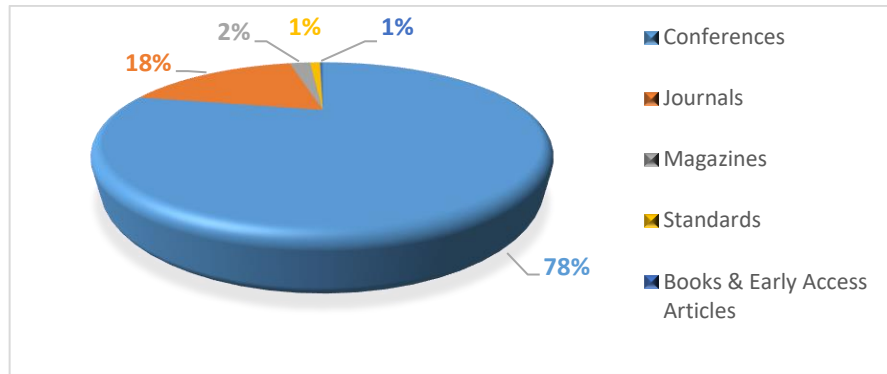


Figure 6. Share of Journals, Conferences, Books, Standards, Magazines and Early Access Articles in Scientific Research Papers on Power Transformer Fault Analysis Published in IEEE Xplore Database in 1974-2023.

The graph shows that most of the scientific works correspond to the works published in scientific conferences. In IEEE Xplore Database in 1974-2023, the share of publications in scientific conferences on power transformer damage is 78%. This means that today many of our scientists have focused on reducing the number of damages to the power transformer, and in the future, many scientific achievements will be achieved as a result of this. Scientific works published in journals occupy the second place with 18%. It is important that many standards have been published among these publications. Up to date, 28 standards have been published on the topic in the IEEE Xplore database, of which 9 are active and 5 are Superseded [7-10].

A number of world scientists have conducted scientific research on the damage of power transformers and its diagnostics. Among them, we can point out the following scientists as an example: Chinese scientist Bozhi Cheng conducted research on the interpretation of the analysis of the frequency effect on the structure of the transformer winding in the city of Manchester. The researcher looked at the circuit as an LC system and studied the effect of the ratio between the series and shunt capacitance on the FRA characteristic, and increased the accuracy of the FRA, but did not pay attention to the circuit's active resistance and inductance [11]. Houssam Ziad El-Hajjar conducted research on the identification of transformer mechanical faults using frequency response analysis [12]. Australian Curtin University professor, senior member of IEEE Ahmed Abu-Siada was engaged in the identification and diagnosis of defects in power transformer transformers [13]. Khrennikov Alexander Yuryevich, a scientist from Samara, who determined the electrical parameters for various types of power plants, conducted research on models for complex diagnostics of parameters of the technical condition of transformer-reactor electrical devices and developed diagnostic models [14]. His student, Alexandrov Nikolay Mikhailovich, conducted scientific research on improving the methods of diagnosing the mechanical condition of power transformer coils [15]. Tomsk scientist Lavrinovich Alexey Valerievich deals with monitoring the condition of the windings of high-voltage power transformers by probing with low-voltage nanosecond pulses [16].

Foundations. Conducting scientific research requires a lot of financial resources. The presence of foundations serves to accelerate the achievement of results in research work. TUBİTAK, Astor transformer Turkey, "Research and development of new smart sensor technology to promote the development of green energy" (202104BN050011) [17, 18] funding, and the "Scientific Research Foundation of Yunnan Provincial Department of Education" (202350134) funding, China [18], Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)-380135324 [19, 20], etc. performed and continue to perform the function of the foundation.

Conclusions. The purpose of writing the article was to determine the degree of relevance of the topic by analyzing the scientific research works published by scientists in the field of power transformer damage. During the analysis, less attention was paid to this field until 2008, and the increase in the number of scientists conducting scientific research within the scope of the topic in the following years shows that the topic is becoming more relevant. This is especially evident in organizations located in Beijing province. The large number of conferences indicates that many new developments will be revealed in the coming days. At the same time, the existence of many foundations for scientific research and scientists who have completed dissertation work on the subject means that this work has a future.

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