9-2-2022

What Makes the Article "Condition Monitoring and Fault Diagnosis of Electrical Motors—A Review" So Popular?

Wei Qiao

What Makes the Article “Condition Monitoring and Fault Diagnosis of Electrical Motors—A Review” So Popular?

Wei Qiao

Wei Qiao (wqiao3@unl.edu) is the Clyde Hyde Professor of Electrical and Computer Engineering at the University of Nebraska–Lincoln, Lincoln, Nebraska, 68588, USA.
ORCID http://orcid.org/0000-0002-7197-4019

Electric motors are widely used in the industrial, commercial, residential, and transportation sectors to power the systems that provide goods and services to end users. The failure of electric motors may cause significant production or service interruption and financial losses. To improve the quality of service of systems driven by electric motors, it is vital to continuously improve the reliability of electric motors. Driven by this demand, various condition monitoring and fault diagnostic techniques for electric motors have been developed by academia and industry over the past decades.

The article “Condition Monitoring and Fault Diagnosis of Electrical Motors—A Review,” written by Subhasis Nandi, Hamid A. Toliyat, and Xiaodong Li and published by the *IEEE Transactions on Energy Conversion*, reviewed the major faults in electric motors and the corresponding fault diagnostic methods that were reported in journal and conference publications and books published between the 1980s and 2005. Such a

Published in *IEEE Electrification Magazine,* September 2022, pp. 83–84.
doi:10.1109/MELE.2022.3187915

Published 2 September 2022.

review provides a bird's-eye view on the signals used and signal processing methods developed before 2005 for the diagnosis of specific faults in electric motors. Such a bird's-eye view helped researchers avoid repeating past work when carrying out research in this field.

Therefore, since the article was published, it has been used by researchers in the field as a major reference in their new publications to discuss the contributions of their work with respect to the techniques developed before 2005, as evidenced by 2,322 citations as of 8 May 2022, according to Google Scholar Citations. The number of annual citations of this article increased continuously from 2006 to 2015 and has stayed steady around 200 in the past five years. The high popularity of this article is mainly attributed to its high-quality, comprehensive review as well as the increasing interest and demand in the development of effective condition monitoring and prognostic health management techniques for electric motors, which have been driven by several major factors: the increasing applications of electric motors in complex tasks that require high reliability; new development of data analytic and artificial intelligence (AI) techniques; interdisciplinary and transformative nature of the research in this field; and significant improvements of computational resources for the implementation of condition monitoring systems.

First of all, electric motors are increasingly used in various sectors of electricity consumption. According to some studies, electric motors consume approximately 70% of the electricity used in the industrial sector and approximately 40–50% of the produced electricity in the world. Therefore, there has been an increasing demand for the online automated fault diagnosis of electric motors because it provides an effective means to reduce the service interruption and financial losses caused by unexpected faults in electric motors. To meet this demand, significant research efforts have been given to develop new fault diagnostic methods for electric motors in the past 15 years. These research and development efforts generated numerous publications and some patents which have used this review article as a major reference to past work or prior art in the field.

In 2005, the use of AI techniques for the fault diagnosis of electric motors was still emerging research. This article was very keen to capture this emerging research by providing a brief introduction to the fault detection of electric motors using AI techniques. Since then, AI-based fault diagnostic methods for electric motors have been increasingly developed. Particularly, in the past several years, research on the condition monitoring of electric motors has been extended significantly from fault detection, which is the focus of the article, to fault type identification, fault location, fault prognosis, and remaining useful life prediction. These significant extensions represent new capabilities that are desirable for the condition monitoring of electric motors and were mainly enabled by new developments in AI and machine learning techniques. Additionally, new data analytic methods have been developed to address the implementation issues of the fault diagnostic systems of electric motors in real-world conditions, such as feature extraction and fault diagnosis under nonstationary operating conditions of electric motors, according to past work in the field discussed in the article.

Moreover, the condition monitoring and fault diagnosis of electric motors has been studied by researchers from multiple disciplines. The two dominant techniques for the fault diagnosis of electric motors are vibration monitoring and motor electrical signal, particularly current monitoring, which have been studied primarily by researchers in mechanical engineering and electrical engineering, respectively. This article reviewed both techniques for the detection of major faults in electric motors and conveyed that motor current signal monitoring was, by far, the preferred technique to diagnose faults due to its merits of low cost and being nonintrusive to the electric motors.

In addition to vibration and motor current monitoring, other fault diagnostic techniques, such as electromagnetic field monitoring, temperature monitoring, acoustic noise monitoring, chemical analysis, radio-frequency emissions monitoring, and so on, were also reviewed in the article. These fault diagnostic techniques involved several different disciplines of science and engineering.

Motivated by leveraging the advantages of different condition monitoring techniques, some researchers developed techniques that fuse the information obtained from multiple condition monitoring signals (called *information fusion*) to improve the fault diagnosis accuracy and reliability for electric motors. Furthermore, some of the fault diagnostic techniques have been transferred or adapted for the fault diagnosis of other types of rotary machine systems, such as gearboxes, wind turbine drivetrains, wind turbine blade pitch systems, and so on. Due to the interdisciplinary and transformative nature of the research in this field, works in the literature that cite this article are not limited to those published in electrical engineering journals and conference proceedings but also include numerous journal and conference publications in other disciplines, such as mechanical engineering, AI, materials science and engineering, aerospace engineering, and so on. This made the article popular in multiple disciplines, which greatly promoted the number of citations of the article.

Traditionally, the condition monitoring and fault diagnosis of electric motors were mainly implemented using local computational hardware and the data collected from local sensors. The limited availability of local computational resources and data restricted the capabilities of the fault diagnostic methods implemented in the traditional condition monitoring systems of electric motors. With the availability and cost reduction of higher-performance computational hardware, more advanced condition monitoring can be implemented locally for electric motors.

Moreover, by utilizing various information technologies, such as communication networks, data centers, cloud computing, the Internet of Things, and so on, the condition monitoring of electric motors can be implemented remotely using big data collected from many motors over their entire lives and almost unlimited computational resources. These improvements in the computational resources have been driving researchers in the field to develop more advanced computational methods not only for the fault diagnosis but also fault prognosis and remaining useful life prediction of electric motors. These new fault diagnostic and prognostic methods can be implemented locally, remotely, in the cloud, or in a distributed manner through communication networks.

Last but not least, the development of effective online fault diagnostic and prognostic techniques will facilitate the shift of the current practice in the health management of electric motors from scheduled/ corrective maintenance to conditionbased predictive maintenance. Such a shift is expected to be able to significantly reduce the maintenance cost, downtime, and associated financial losses caused by the failure of electric motors. Therefore, this article also provides an important reference for researchers in another broader, thriving field called *prognostic health management*. There is no doubt that this article will continue to be popular because of the many new developments to come in the field of the condition monitoring and prognostic health management of electric motors and related fields.