Advanced Engineering Days

aed.mersin.edu.tr

Detection of short circuit fault in axial flux machines with finite element method

Eyyüp Akcan*[1], Mehmet Rida Tur[2] Eklas Hossain[3]

[1] Batman Vocational and Technical Anatolian High School, 72100 Batman, Türkiye, eyupakcan@hotmail.com
[2] Batman University, Electrical and Energy Department, Batman, Türkiye, mrida.tur@batman.edu.tr
[3] Oregon Tech, Department of Electrical Engineering & Renewable Energy, OR-97601, USA

Cite this study: Akcan, E., Tur, M.R. & Hossain, E. (2022). Detection of short circuit fault in axial flux machines with finite element method. 2nd Advanced Engineering Days, 16-18

Keywords
Fault Detection
Axial Flux
Short Circuit

Abstract

Axial Flux Permanent Magnet (AFPM) machines have many unique features due to their high torque and power density motors. On the other hand, these machines have disadvantages such as short circuit, demagnetization and rotor eccentricity, which should be considered in application and maintenance. It is important to detect short-circuit faults that occur in axial flux permanent magnet machines before they occur. Failure of these machines will adversely affect their operation. In axial flux machines, both healthy and faulty analyzes can be made with the finite element method. Thanks to this analysis, it will be possible to see whether changes occur in the behavior of the machine. The axial flux permanent magnet machine to be designed can be tested by using the finite element method. The features of the stator output signals obtained by the finite element method are extracted by applying the fast Fourier transform (FFT), these features are kNN and RF, etc. It can be aimed to separate using classification methods.

Introduction

Electric motors have existed since the middle of the 19th century and have become an integral part of modern life by increasing its importance until today. Asynchronous motors, DC motors and synchronous motors are important motor types commonly used in industry. There are billions of different sizes and types of engines in the world and they are used everywhere in homes, vehicles, businesses and industries. These machines are generally produced as single-phase and three-phase and provide great convenience to human life in daily work. There are many studies to improve engine efficiency and usability, and research is still ongoing [1].

In the last decade, permanent magnet synchronous machines (PMSMs) have gained significant popularity in applications such as wind turbines and electric vehicles due to their higher efficiency, high output power, volume ratio and high torque, current ratio. Therefore, permanent magnet machines have an important place in industrial applications. In these mission critical applications, an unexpected machine failure or demagnetization failure can affect machine performance, resulting in very high repair or replacement costs or even catastrophic system failure. Therefore, a robust and reliable health monitoring and diagnostic approach is desirable that can help schedule preventive maintenance to prolong their life and prevent machine failure. Because offline machine diagnostics and diagnostic methods do not allow frequent testing and are financially impractical, many online methods have been proposed by researchers to reduce maintenance costs and provide more reliable diagnosis. A cost-effective way is based on the stator current spectrum, often referred to as motor current signature analysis (MCSA) [2].

Material and Method

In order to diagnose the short circuit fault that may occur in the machine, a correct short circuit analysis is required. Many researchers have examined these fault characteristics from different perspectives. Permanent magnet flux linkage estimates are reported for velocity hormonal analysis under different loads, speeds, and temperatures in [3]. When using these methods, using only one characteristic information may not be sufficient for fault detection [4]. Characteristic information such as magnetic flux, current, voltage, acoustic sounds, temperature, vibration and torque are needed to detect faults. Many methods are suggested in the literature for short-circuit fault detection. Among these suggested methods, there are successful methods used for fault diagnosis.

In order to diagnose short circuit faults that may occur in the machine, current and voltage fault signals should be compared with healthy signals. In order to obtain current and voltage signals for healthy and faulty situations at different speeds and loads, analyzes are made with the finite element method. In this machine, one of them is healthy and one of them is short-circuit fault at different percentages. Figure 1 shows a 3D view of a machine.

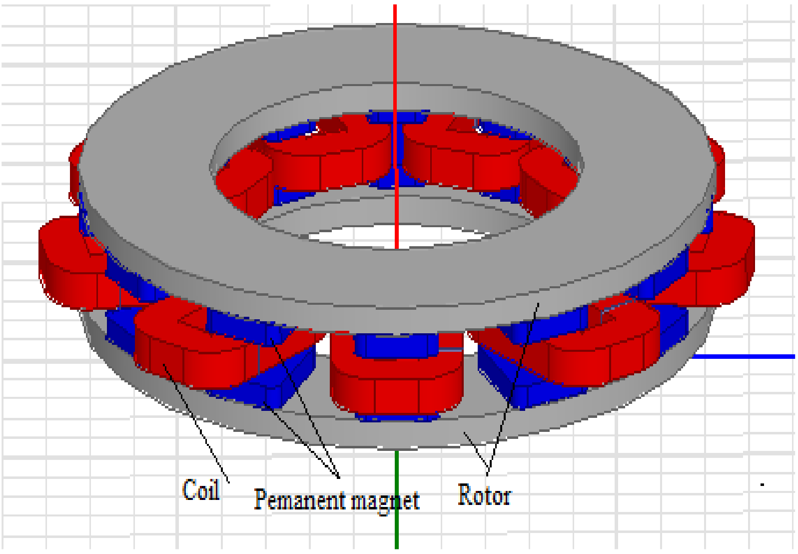

Figure 1. View of the axial flux permanent magnet generator. Permanent magnets: dark blue. Rotors: in gray color. Stator windings: in red [5]

Techniques of Fault Detection

With the developing computer technologies, the amount of data being used is growing rapidly; The rapidly increasing amount of data also makes it difficult to analyze these data. According to one estimate, it is stated that the amount of data in the world doubles every 20 months [6]. Obtaining information from a signal using the appropriate signal processing tool, followed by appropriate data mining technique, accurately specifying the engine condition is very important for additional diagnosis of the fault [7].

Nearest Neighbor K-NN

The K-NN algorithm is a classification method proposed by T. M. Cover and P. E. Hart, in which the class in which the sample data point is located and the nearest neighbor are determined according to the k value. This algorithm is one of the best known, old, simple and effective pattern classification methods and is widely used among machine learning algorithms. Classification of objects is an important research area and is applied in a wide variety of fields such as pattern recognition, data mining, artificial intelligence, statistics, cognitive psychology, medicine, bioinformatics. The K-NN algorithm is among the most basic example-based learning algorithms. In example-based learning algorithms, the learning process is carried out based on the data held in the training set. A newly encountered example is classified according to the similarity between the examples in the training set. In the K-NN algorithm, the samples in the training set are specified with n-dimensional numerical features. All training samples are held in an n-dimensional sample space, with each sample representing a point in n-dimensional space. When an unknown sample is encountered, the k closest samples are determined from the training set and the class label of the new sample is assigned according to the majority vote of the class labels of its k nearest neighbors [8].

Random Tree (RT)

Decision trees are a type of tree-shaped decision structure, whose classes are learned by induction from known sample data. A decision tree is a structure used by dividing large amounts of records into very small groups of records by applying simple decision-making steps. With each successful division, the members of the result groups become more and more similar to one another. Decision trees are a useful solution for many classification problems using large databases and complex or error-prone information. Decision trees, which have predictive and descriptive features, are the most widely used technique among classification models because they are easy to set up, easy to interpret, easily integrated into database systems, and have better reliability [9].

Short-circuit Fault in Axial Flux Machine

The short circuit faults that occur in the axial flux machine are the faults that occur between the windings. It affects the required performance and efficiency of a machine with a short circuit fault in the stator. A short-circuit fault in the machine causes an increase in temperature between the windings and creates a short-circuit with other windings and negatively affects the operation of the machine. In this study, the short-circuit fault created will cause the machine's features to be lost to some extent. Based on the current signals generated as a result of the short circuit fault, k-NN and RT classification methods were used. Comparison of this classification method in Table 1.

Table 1. Comparison of short-circuit fault classification methods in axial flux machines

Axial Flux Machine Classification	K NN	RT
Accuracy Percentage (%)	98,76	100

Results

In this study, fault diagnosis is made for short circuit fault in axial flux permanent magnet synchronous machines. It is very important for the early detection of malfunctions in electrical machines. It both reduces maintenance costs and prevents major malfunctions that may occur in the machines. Therefore, the current and voltage signals obtained by the finite element method will be featured by applying fast Fourier transform (FFT). These features are decomposed using k-NN and RT classification methods. These results have been shown to be a useful method for short-circuit fault detection in axial flux permanent magnet synchronous machines. A comparison of the classification methods used for this method was also made. As a result of these comparisons, it can be said that the defective signals are completely separated from the healthy signals in the k-NN and RT classifications used.

References

[1] Minaz, M. R. (2017). Nüvesiz bir eksenel akılı senkron generatör tasarımı ve simülasyonu (Doctoral dissertation).

[2] Da, Y., Shi, X., & Krishnamurthy, M. (2012). A new approach to fault diagnostics for permanent magnet synchronous machines using electromagnetic signature analysis. IEEE Transactions on Power Electronics, 28(8), 4104-4112.

[3] G. Feng, C. Lai, & N. C. Kar, "Particle-Filter-Based Magnet Flux Linkage Estimation for PMSM Magnet Condition Monitoring Using Harmonics in Machine Speed," IEEE Trans. Ind. Informatics, 13(3), 1280–1290, 2017.

[4] M. Zhu, W. Hu, and N. C. Kar, (2018). Multi-sensor fusion-based permanent magnet demagnetization detection in permanent magnet synchronous machines. IEEE Trans. Magn., 54(11), 1–6

[5] Minaz, M. R., & Çelebi, M. (2017). Analysis and Design of an Axial-Flux Coreless Permanent Magnet Synchronous Generator with Single Stators and Double Rotors. International Journal of Energy Applications and Technologies, 4(1), 7-11.

[6] Witten, I. H., Frank, E., Hall, M. A., & Pal, C. J. (2005). Data Mining: Practical Machine Learning Tools and Techniques (The Morgan Kaufmann Series in Data.

[7] Panigrahy, P. S., Konar, P., & Chattopadhyay, P. (8-10 Jan. 2016). Application of data mining in fault diagnosis of induction motor. IEEE. Kolkata, India.

[8] Taşcı, E., & Onan, A. (2016). K-en yakın komşu algoritması parametrelerinin sınıflandırma performansı üzerine etkisinin incelenmesi. Akademik Bilişim, 1(1), 4-18.

[9] Albayrak, A. S., & Yilmaz, Ö. G. Ş. K. Ver Madenc L Ğ: Karar Ağaci Algor Tmalari Ve Mkb Ver Ler Üzer Ne Br Uygulama Data Mining: Decision Tree Algorithms and An Application on Ise Data.