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Diagnosis of eccentric fault using support vector machine algorithm

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***Abstract*-Three-phase induction (IM) motors are popular in domestic and industrial appliances because they are ruggedly built, require little or no maintenance, are relatively inexpensive, and require only one power supply to the stator. But fault occurrence in such motors may lead to failure of machine so it's very important to detect fault at an early stage in order to avoid production loss. This paper proposes an effective and intelligent fault diagnosis of eccentric fault using Support Vector Machine (SVM) algorithm. It is supervised machine learning technique having ability to process data without losing prior learning makes SVMs suitable for online monitoring and error analysis in real-time programs. Different parameters with loading effects of IM under healthy and faulty conditions are compared. Furthermore, the variation of stator current is utilized as features in the fault detection and classification using SVM classifier for accurate diagnosis.**

Index Terms – Static Eccentricity (SE), fault detection, SCIM, SVM, stator current

1. Introduction

The majority of motors used in industries are three-phase Squirrel Cage Induction Motor (SCIM). Since these motors are highly-reliable and of low cost, they are also the preferred choice for industrial applications due to high efficiency [1,2]. Now a days due to advancement in machine computing, various methods like Supported Vector Machines (SVM) [3], k-Nearest Neighbors (kNN) [4],Decision Trees (DT) [5], and deep Learning methods [6] are commonly used. Machine learning and artificial intelligence techniques plays an important role in for detection and classification of different errors [7, 8].

This research work presents dignosis of static eccentric fault. Eccentricity is common mechanical fault in electrical machine. Roughly, 80% of the mechanical errors responsible for the eccentricity. Eccentricity fault may occur during manufacturing and assembling process. In eccentricity fault the distance between the rotor and stator in the air gap is uneven [9]. Eccentricity error includes static eccentricity and dynamic eccentricity, and the sum of both is mixed eccentricity. Within the SE, the rotor's axis of symmetry coincides with the rotor's axis of rotation, but is many miles away from the stator's axis of symmetry. In this example, the distribution of the air gap around the rotor is uneven, but the minimum angular roll of the air gap is constant. SE errors are generated by transferring the geometry of the stator. However, static eccentricity can also cause dynamic eccentricity. If the rotor shaft assembly is stiff enough, the magnitude of static eccentricity will not change. Due to the air gap asymmetry, the stator current has a well-defined component that can be detected.

1.1 Fault Diagnosis using Support Vector Machine

SVMs have become increasingly more popular in various disciplines of science and technology, due to many attractive capabilities, along with precision and performance in modeling and empirical performance [10,11]. So, the main emphasis of this research work is detection and classification of eccentric fault using SVM.

The main step in fault diagnosis using SVM is feature extraction of stator current signals which are processed using the DWT characteristic extractor and the characteristics are calculated for all collected data sets. Stator current is the primary monitoring signal in motors for fault detection because it is accessible and inexpensive [12,13]. After then the fault functions are divided into classes and the set of complete data is split into training and testing. Consequently, Support Vector Machine with linear kernel function as classifier is applied to training a well test data set to maintain accuracy. The entire diagnosis process is shown in the flow chart in Fig.1.

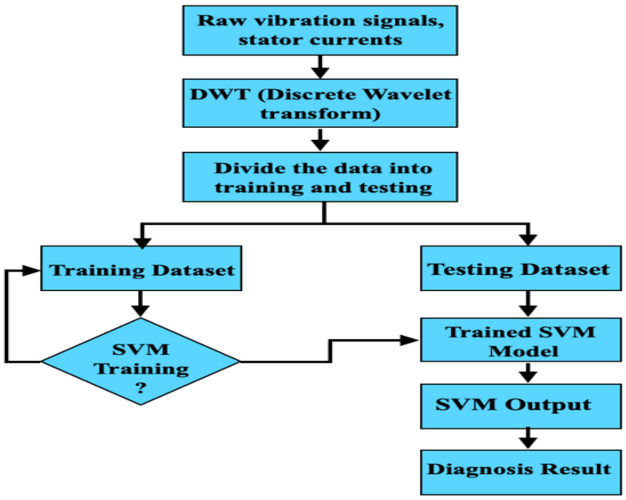

Fig.1: Flow chart of SVM based IM fault diagnosis

2. Result and Discussions

The MATLAB model of SCIM model with rating of 5kW power and 415V rated voltage is simulated to investigate the motor performance under healthy and static eccentric fault condition. To extract the features from its stator waveform behavior and apply the SVM method to detect these faults as soon as they appear in the motor.

2.1 Healthy condition

Implemented model is operated under healthy operating condition and different performance parameters like voltage, speed, current and torque are considered to analyze motor behavior as illustrated in Figures 2, 3, 4 and 5.

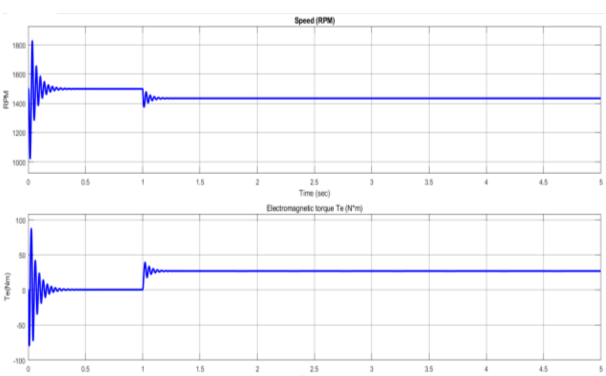

Fig. 2: Speed (rpm) and torque (Nm) at 100% loading condition

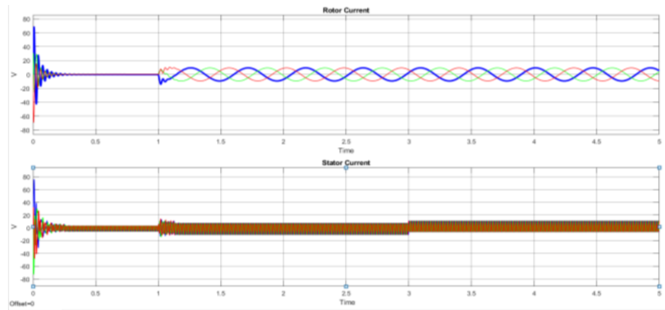

Fig. 3: Rotor and stator current (A) at 100% loading condition

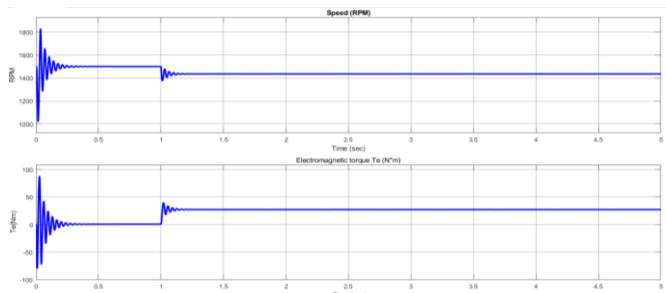

Fig. 4: Speed (rpm) and torque (Nm) at 50% loading condition

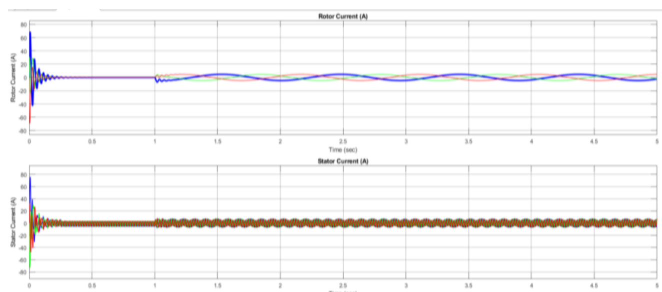

Fig. 5: Rotor and stator current (A) at 50% loading condition

2.2 Static Eccentric Fault in SCIM at Full Load

The MATLAB model with static eccentric fault in SCIM is operated under various loading conditions. The motor characteristics obtained at full load are shown in Fig. 6 and Fig. 7. The rotor and stator current is depicted in Fig. 6 and Fig. 7 shows the torque and speed at the full load torque obtained is 23.04 Nm and speed attained at full load is 1197 rpm.

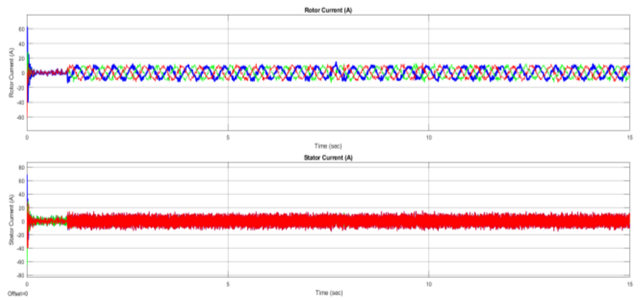

Fig. 6: Rotor and stator current of static eccentric fault in SCIM at Full load

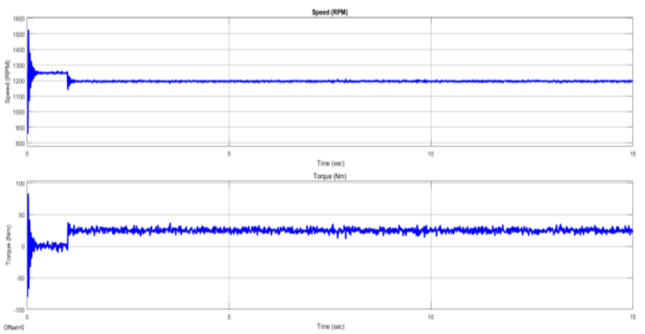

Fig. 7: Speed and torque of static eccentric fault SCIM at Full load

2.3 Static Eccentric Fault in SCIM at 50% Load

The motor is now set at 50% loading condition and its characteristics obtained shown in Fig. 8 and Fig. 9. The rotor and stator current as illustrated in Fig. 8 and the torque and speed at the 50% load is shown in Fig. 9. The torque obtained is 10.90 Nm and the speed developed in motor is 1225 rpm. The static eccentric fault degraded the performance of the motor at all loading conditions.

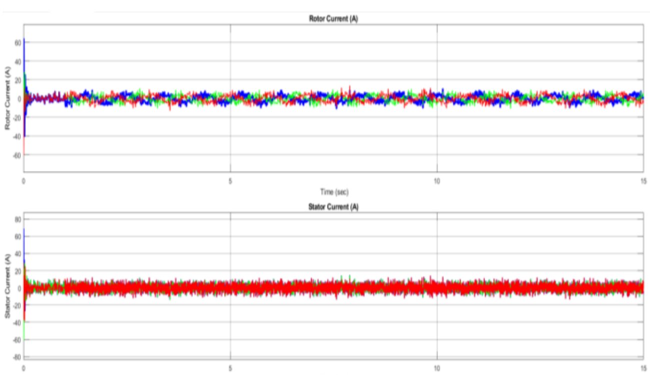

Fig. 8: Rotor and stator current of static eccentric fault in SCIM at 50% loading

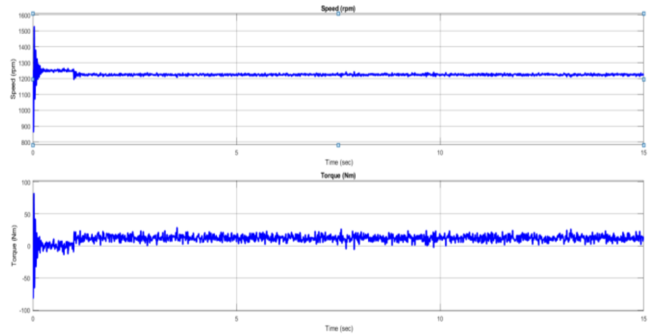

Fig. 9: Speed and torque of static eccentric fault in SCIM at 50% loading

Table 1 : Three-phase SCIM performance at different loading conditions under healthy condition

Loading Conditions	Torque (Nm)	Speed (rpm)
Full Load	27.17	1435
Half Load	13.82	1468
Quarter Load	7.14	1484

Table 2: Static eccentric fault SCIM motor speed and torque at different loading conditions

Loading conditions	Torque (Nm)	Speed (rpm)
Full Load	23.04	1197
Half Load	10.90	1225
Quarter Load	4.82	1238

Table1 and Table 2 summarizes the healthy and static eccentric fault motor behavioral characteristics respectively. The torque produced at full load is 23.04 Nm which is lesser as compared to healthy condition output and the speed is 1197 rpm at full load. The designed motor is put under varied loading condition to generate the data for the classification at later stage and to analyze the behavior which will be further utilized to classify the fault type.

2.3 Fault Detection and Classification based on SVM

Signal processing technique DWT is applied for extraction of the features of stator current signals of healthy motor and faulty motor with static eccentric fault under different loading conditions as shown in Figures 9 and 10.

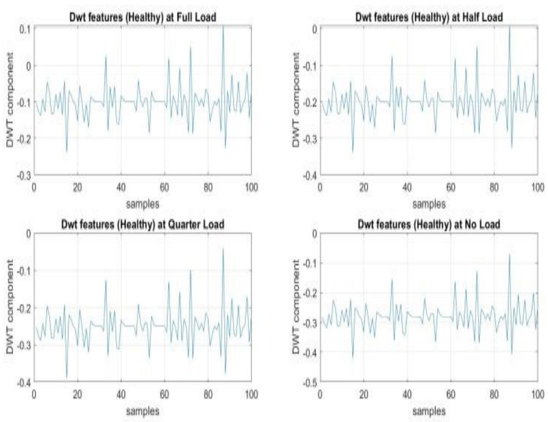

Fig. 9: DWT features extracted in healthy operating condition at full, half, quarter and no loads

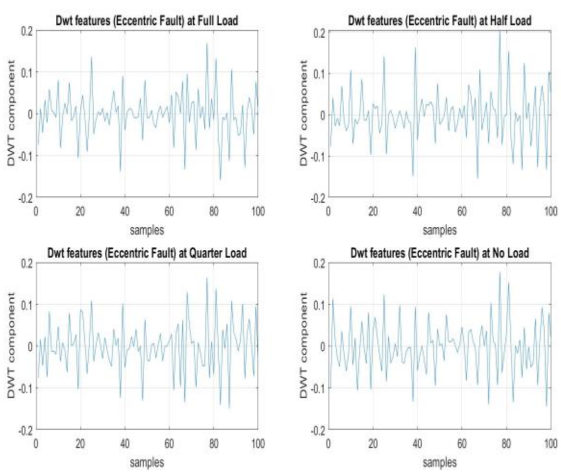

Fig. 10 : DWT features extracted in static eccentricity faulty operating condition at full, half, quarter and no loads

The classification task generally involves the use of two data sets, training and test data. The total data collected samples of healthy and faulty conditions is divided as training data 70% and testing data 30%. SVM can be thought of as a binary output classifier. Classification relies on splitting the tested data into two main classes. N-fold cross-validation is used for testing. Such validation divides the statistical sample set into complementary N subsets. The first subset is used to test the model trained on the remaining subset of N
subsets. Analysis is performed on a subset called the training set. Validation analysis is performed on another subset called the validation set or test set. The process is repeated for the next subset, etc. To reduce variability, the above procedure is performed for multiple iterations on different N partitions of the entire set and the validation results are replicated across rounds averaged. This process is repeated for N rounds.

The testing data confusion matrix at all different constant loading conditions as depicted in Table 3(a and b) utilized for calculating the accuracy, precision and recall. The obtained overall accuracy in fault diagnosis is 97.5%. Precision and recall of the SVM is 0.97.

Table 3 (a and b) Confusion matrix at 100% and 50% loading conditions using SVM as classifier

Healthy	290	0	1	0	0	0	0
Rotor	0	150	0	2	0	0	0
Stator	2	0	148	0	0	3	1
Eccentric	0	0	0	145	2	2	0
Rotor-Eccentric	5	0	1	1	147	0	3
Stator-Eccentric	3	0	0	0	0	145	0
Rotor-Stator	0	0	0	2	1	0	146
	Healthy	Rotor	Stator	Eccentric	Rotor-Eccentric	Stator-Eccentric	Rotor-Stator

(a)

Healthy	290	0	1	0	0	0	0
Rotor	0	147	0	2	0	0	0
Stator	2	1	145	0	0	3	1
Eccentric	0	0	0	145	2	2	0
Rotor-Eccentric	5	1	2	1	147	0	3
Stator-Eccentric	3	1	1	0	0	145	0
Rotor-Stator	0	0	1	2	1	0	146
	Healthy	Rotor	Stator	Eccentric	Rotor-Eccentric	Stator-Eccentric	Rotor-Stator

(b)

3. Conclusion

The research work based on diagnosis of the static eccentric fault in induction motor with its classification using SVM algorithm. Variours performance parameters under different loading conditions of motor are obtained from SCIM model simulated in MATLAB software. Further, the feature extraction is done using DWT for stator current signals. The DWT feature extractor provides current signals into electrical signals in an efficient way and database created for fault occurrences in SCIM. Dataset is then utilized for supervised learning process divided into training and testing with 10-k fold cross validation approach for SVM. Features are extracted and divided in different sets at 100% and 5% loading conditions to analyze the performance of algorithm at different severity level of the fault. Subsequently, the detection and classification of the fault under all loading conditions is performed with high accuracy.

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