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Detection of DC Voltage Fault in SRM Drives Using K-Means Clustering and Classification with SVM

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ABSTRACT: *This paper presents a new method of detection of DC voltage fault in SRM drives based on K Means Clustering technique. Also the range of fault is classified using Support Vector Machines (SVM). Switched reluctance motors are very popular in these days, because of ease in manufacturing and operation. Though an electronic circuit can detect the fault like under voltage and over voltage but, the classification cannot be done effectively with electronic circuitry. More over an intelligent method can easily identify the fault and classify and hence the root cause of the fault may be guessed and rectified using this method of classification. The information used to include this intelligence in the system are just torque waveforms. Moreover, the early detection minimizes the faulty operation time and ensures the plant stability and saves the life of motor too. Hence a system to detect such fault under a simulation model has been proposed in this study.*

Keywords: *K Means Clustering, SRM (Switched Reluctance Motor), SVM (Support Vector Machines)*

I. Introduction

The applications of SRM in aircraft and industrial automations applications are enormous and need a perfect flaw free operation to obtain the required electrical and mechanical outputs from the motor [1]. The absence of rotor windings and permanent magnets in rotor makes the manufacturing of SRM easy and hence the SRM is very popular in market based on commercial aspects too. The special feature of SRM is that, a particular phase of SRM is not influenced by the other phase and is very negligible. Hence, the motor continues to rotate even at faulty conditions but it might not produce the exact required output parameters based on mechanical aspects. So, early detection of the faults in SRM is mandatory. The salient pole configuration of the SRM is responsible for ripples in torque, anyhow that can be minimized using the works in [2]. The major issue with faulty operation is that, though the motor continues to rotate, the mechanical forces become imbalanced and the mechanical power decrease proportional to the number of phases disconnected from the circuit.

Open circuit faults have not been given much importance in earlier literatures except [1]. Open circuit can be easily identified with the presence or absence of the phase current. A typical electronic circuit would do it. But the circuit fails to classify the faults if the numbers of faults are more and more over the time instant of fault occurrence is never known with circuit based detection. In addition to the above said draw backs of circuit based detection, the circuits needs the sensors which are likely to fail. Also the number sensors to be used is proportional to the number of phases, which considerably increases the cost of the system. Hence a processor based intelligent device may be suitable at these circumstances.

Fault tolerant systems are abundant in market, in which the motor can continue with its operation even at faulty conditions like, open, short and phase to phase shorts as given in [3]. This study would be a main source for all other further AI based fault detection systems. But such models were unable to classify the various faults, so remedial action could not be taken against the faults. The authors of this study feel that apart from the fault detection, fault classification becomes essential in order to impart intelligence to the machines. As in [4] certain works had been done using fuzzy controller to stablize the SRM. The papers [1], [5], [6], [7]and [8], discusses about the various power converters and faults likely to occur and methods to detect the faults. To the best of the author's knowledge, clustering algorithms and SVM based classification techniques had not been used in SRM fault detection.

This study has been organized as follows: Section II, describes the concept of K means clustering techniques, Section III deals with SVM classification techniques, Section IV discusses about the proposed method and the simulation outputs are discussed in section V.

II. K-Means Clustering

Clustering is a method of grouping similar data into various groups based on the amplitude of the data points. This is an iterative scheme to find the local minimal solution. This clustering method has been clearly shown in [9]. Optimal placement of the center at centroid is the technique behind this algorithm. Let us suppose that N numbers of data points are the outcome of an experiment. These data points are clustered into K number of clusters, with each cluster consisting the number of elements which depends on the value of the data points. Mathematical investigation of k means algorithms is beyond the scope of this study. In our work, the feature vectors for detecting the DC voltage fault is extracted from using this k means clustering. The corresponding waveforms and results are shown in section V.

III. Support Vector Machine Based Classification

The basic idea behind the SVM classification technique is to identify the class of the input test vectors. This is a supervised learning algorithm, where the training vectors are used to train the system to map these training vectors in a space with clear gaps between them using some standard kernel functions and the input test vectors are mapped on to the same space to predict the possible class. The choice of the kernel functions have been discussed in [1]. Given some training data D, a set of n points of the form:

$$D=\{(x_i,y_i)\mid x_i\in \mathbb{R}^p, y_i\in\{-1,1\}\}_i^n=1 \quad (1)$$

Where, y_i is either belonging to the class 1 or class-1, which means the class which the point x_i belongs. Each x_i is a p-dimensional real vector. While classifying, it is essential to find the maximum possible margin hyper plane that segments the data sets having y_i = 1 from those data sets having y_i = -1. So any hyper plane can be written as data sets X satisfying maximum possible margin hyperplane and margins for an SVM trained with samples from two classes. Samples exactly on the margins are called the support vectors:

$$W.X-b=0 \quad (2)$$

Where . denotes the dot product and is the normal vector to the hyper plane. The term b/||w||determines the offset of the hyper plane from the origin along the normal vector W. In case, the training data sets are linearly separable, then two hyper planes can be constructed in such a way that they group the data sets and there are no points between them and then tried to increase the distance among them. The region surrounded by them is called "margin".

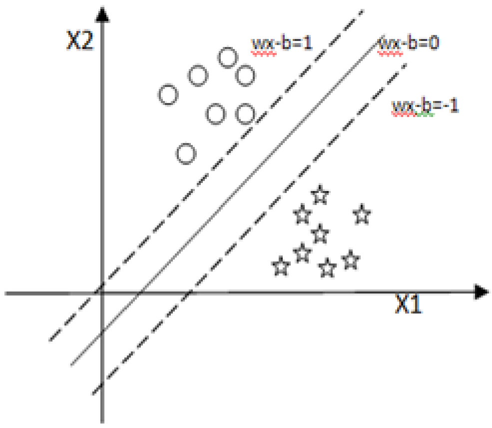


Figure 1: SVM Scenario

These hyper planes can be described by the equations:

$$w.x-b=1 \quad (3)$$

and

$$w.x-b=-1 \quad (4)$$

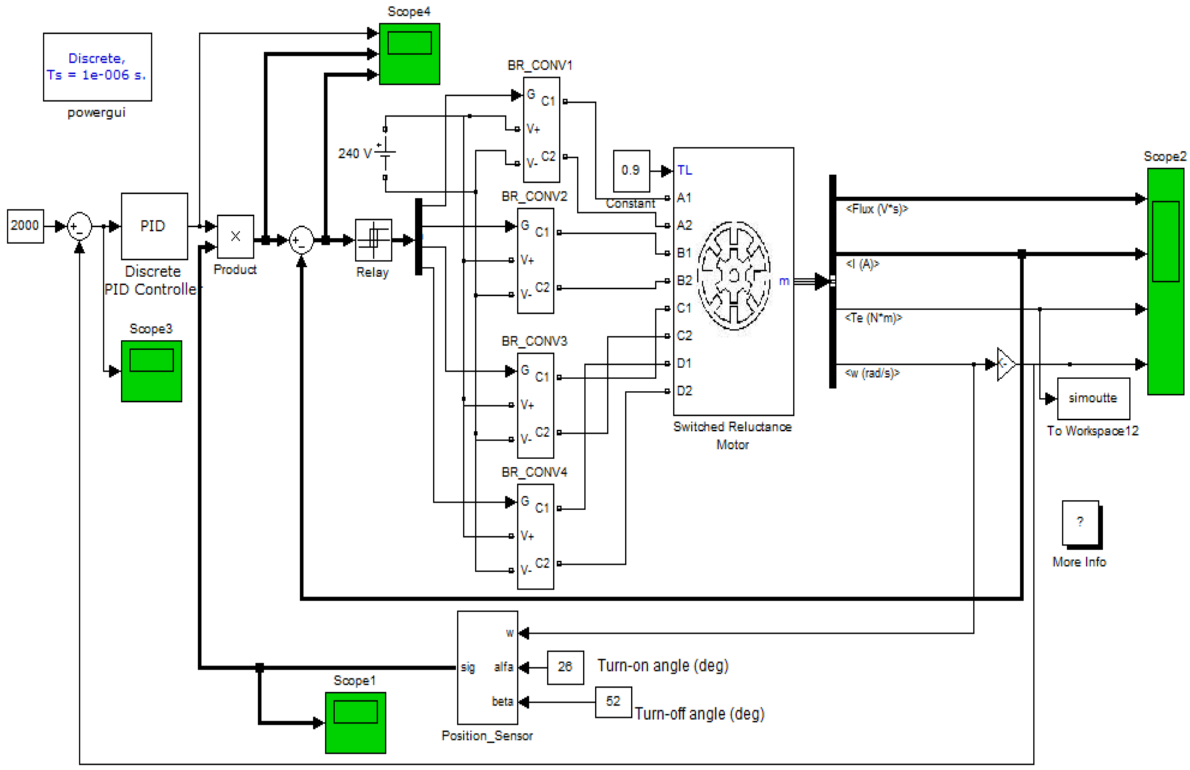
Fig. 1 shows the process of how two data sets (one represented by circles and the other set by stars) are classified in two different regions while a linear kernel is used for classification. In the testing phase, the data points x_i are separated using the following constraints w.xi-b≥1 for x_i of the first class or w.xi-b≤1 for x_i of the second class.

IV. Proposed Fault Detection Method

There exist two types of motoring operation based on the health of motors, Normal operation and faulty operation. These modes of operation are well discussed in [1]. The major contribution in this study is to detect the dc voltage fault and classify it. This method of detecting the fault is achieved through an efficient method of feature selection and classification. DC voltage shift directly reflects in the magnitude of the torque ripples hence the range of torque ripples can be used to detect the range of DC voltage. These online values of torque data is clustered and features are classified to find the voltage fault. This method is very useful when the electrical drive circuit is far away from the worksite of the motor. The DC voltage faults usually create a flux to deviate from its healthy condition. These flux values are clustered to find the mean value of the data points and number of data points in each class. This is done using k means clustering. These clustered values are classified using Support Vector Machines (SVM).

V. Simulation And Outputs

Fig. 2 shows the simulation model of the proposed fault detection method for DC voltage fault. First the SRM drive is simulated at healthy condition and the corresponding Flux, Stator current, Torque variations and Speed outputs are obtained. Then the DC voltage faults are created and the same parameters, Flux, Stator current, Torque variations and Speed are shown.



DC voltage Fault detection in Current-controlled 8/6 Switched Reluctance Motor drive

Figure 2: Simulation model of SRM

5.1. Healthy Conditions

A Matlab simulink model of the SRM drive with 8/6 configuration has been designed and simulated with all the switches at perfect healthy conditions. The parameters have been shown at steady state. Load torque is set as 0.9. Fig. 3 shows the output of the healthy SRM drive with a speed of 2000 rpm ,where it can be noted that, the torque ripples have an offset of 9 N-m . The parameters like, Flux, Stator current, Torque variations and Speed are shown.

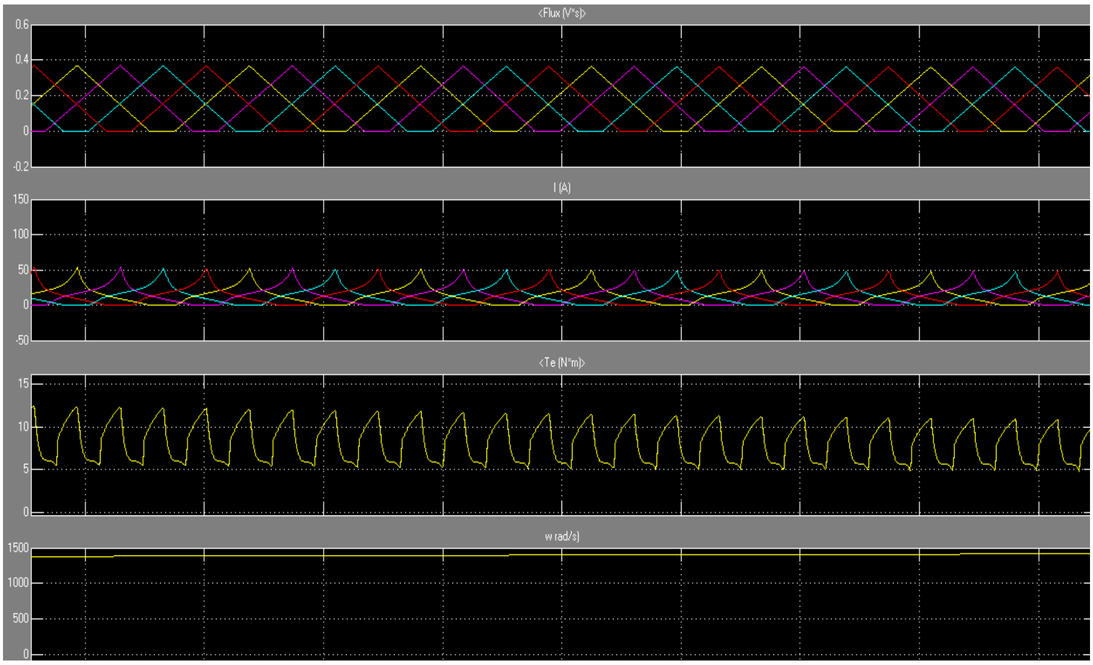


Figure 3: Steady state waveforms of flux, current, torque and speed at healthy conditions

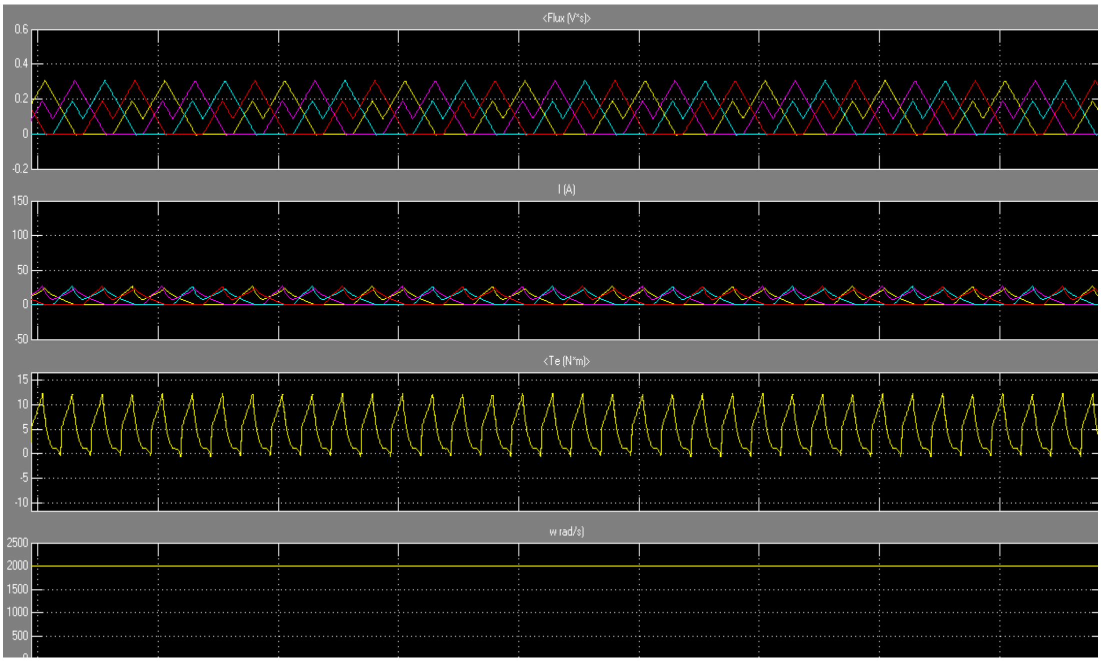


Fig. 4. Waveforms of flux, current, torque and speed at dc voltage fault

5.2 DC Voltage Fault Conditions

DC voltage fault is nothing but, a variation in the DC link voltage which is to be inverted further to apply for stator coils. This reduction or increase in DC will reflect in dc offset of ripples in torques, the offset in the captured waveform is around 5 N-m. So the major task is to follow the torque waveforms. This method is very suitable to detect the faults when the control circuit and the motor is at a distant place. In this DC voltage faults, k = 10 is chosen to cluster the torque wave-forms. Two voltage conditions of 240 V, a full rated voltage and 120V, half of the rated voltages were applied to excite the SRM. Based on the number of elements in cluster, Classification using SVM is performed to identify the DC bus fault. The faulty torque waveforms at V=120 volts is shown are shown in the Fig. 4.

VI. Conclusion

In this study, a K - Means clustering based method to detect the DC voltage fault in SRM and classification based on SVM has been implemented. Hence, earlier detection of DC voltage faults increases the life time of the SRM. Implementation of this simulation as a real time system requires a high speed processor to perform all mathematical calculations along with high speed Analog to digital converters at online. The future extension of this work may be concentrated on multiple DC levels of the input voltage, and the major merit in our work is that this method can be applied to any type of motors.

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