Multiple Fault Detection in Induction Motor

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ABSTRACT

Detection of faults in the induction motor has been a challenging task for researchers and engineers in industry. If the fault is not detected in the premature stage it will lead to system shut down causing production losses. In motor number of faults can be present at the same time. The detection of these faults is crucial to save maintenance time and production losses. Vibration signal monitoring techniques are implemented for the internal fault detection. This is because current monitoring techniques are used for the detection of faults. But current monitoring does not provide reliable results. These vibration signals are collected by using accelerometer. For the external fault Detection , voltage and current signals of three phases are studied. Time domain and frequency domain techniques have been implemented for the detection of internal faults using MATLAB. This thesis presents efficient and cost effective solution for the detection of faults. Various classification techniques have been implemented for the detection of external faults: under voltage fault, over voltage fault, overload, single phasing and voltage unbalance. The detection of these faults is important as it will increase the reliability and efficiency of the motors.

Keyword: Induction machine, Faults, KNN

INTRODUCTION

The economical, high efficiency, low maintenance, robust design and construction of induction motors have emboldened their outstanding application in industry as well as in household for many years. It has been assessed that almost 75% of the electric motors found in the industry are induction motors [1]. Although all of the motors are prone to faults but induction motors are first
for the occurrence of the fault. If not detected in earlier stages, the occurrence of an incipient fault will eventually cause a machine failure. Even though the fault is severe, due to limitations as the size of sensors is large and is expensive, the methods of traditional fault detection are not applied to the small machines and are only applicable to larger machines.

The characteristics of the motors such as current, voltage, speed, vibration, temperature, sound,
etc., can be applied for the fault detection and condition monitoring in a motor. These characteristics will change, when any fault occurs in the motor. The condition of the motor can be judged by comparing these characteristics. An induction motor consists of two electrical circuits connected with the help of a magnetic circuit. The stator is the stationary part while rotor is the rotating part. The rotor is supported by bearings at both ends. Faults or abnormalities appears in the induction motor can be classified in these two classifications, external and internal faults. Overload (OL), under-voltage (UV), overvoltage (OV), Single phasing (SP), voltage unbalances (VUB), locked rotor, earth fault between supply feeder and motor terminals and 3 phase fault at the terminals are categorized as external faults, whereas bearing faults, stator faults, rotor faults, eccentricity in the air gap and short circuit are internal faults. Internal as well as external faults accurate diagnosis is equally necessary and which can be lead to development of comprehensive protective scheme for all faults.

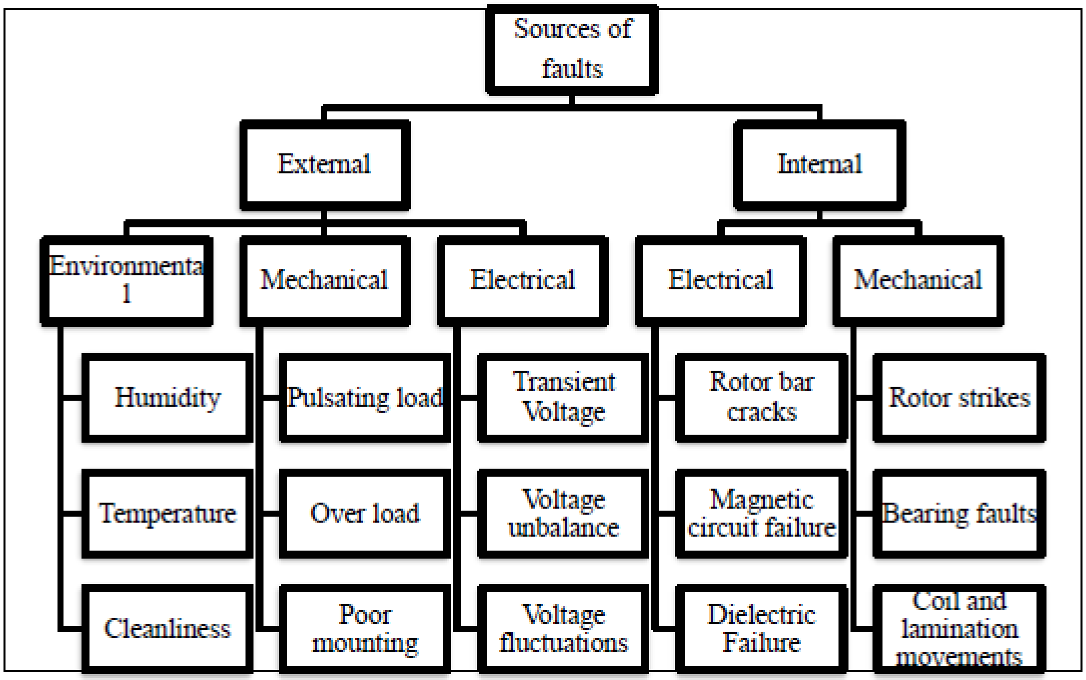
BACKGROUND

Induction motors are prone to various types of faults. In this chapter background of various internal and external faults of the induction motors is discussed. Also, we will discuss the various
traditional as well as modern techniques of fault detections.

Types of faults

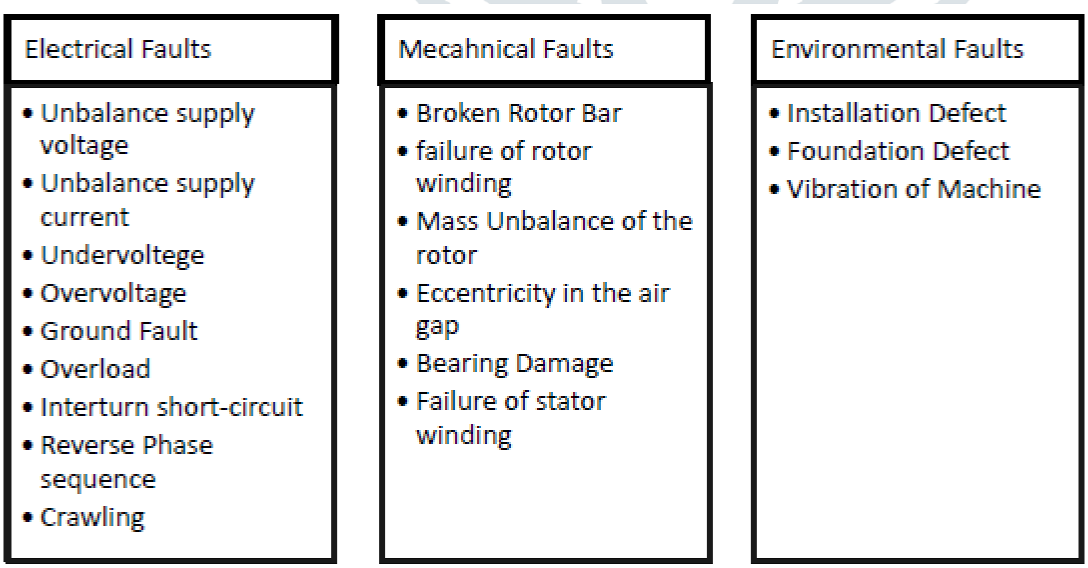
Depending upon the sources of the fault in the induction motor. Faults can be classified as internal or external [2]. Internal faults are caused by the internal conditions of the motor like wear and tear, short circuit, etc. On the other hand, the external faults are caused by external conditions like environmental causes or fault outside the machine, etc.

Sources of Faults in I



Following is the categorization for the faults present in the induction motor [3]:
 Mechanical-related faults: stator winding failure, rotor winding failure, bearing damage, mass unbalance, broken rotor bar and air gap eccentricity are covered under this classification.

 Electrical-related faults: Over voltage, under voltage, single phasing, earth fault, overload, unbalance supply voltage, unbalance current, crawling, reverse phase sequence and inter turn short circuit are categorized under electrical related faults.
 Environmental-related faults: The performance of the induction motor will be affected by the ambient temperature and outside moisture. Whereas, vibration of the motor caused by any foundation or installation defects will further affect performance of IM.



Causes and Effects of Internal Faultsof Induction Motor

Type of Fault	Cause		Effect
Bearing Fault	Fatigue Failure	Long run of motor, Corrosion, Contamination of foreign particles	Fracture of motor Increase in Noise and Vibration
	Lubricant Failure	High temperature,	High wear of balls, Overheating
	Misalignment of bearing	Wear of balls and races	Increase in temperature and vibration
Stator Fault	Mechanical Stress	Striking of rotor and stator coil due to shaft misalignment	Open circuit fault
	Electrical stress	Supply voltage transient due to lightning, LG, LL, LLL faults and VFDs.	Turn to Ground and turn to turn faults
	Thermal Stress	Overload, higher ambient temperature, Unbalanced Voltage Supply, etc.,	Insulation life is reduced
Rotor Faults	Broken Rotor Bar	Manufacturing Defects, Large centrifugal Forces due to heavy end rings, Thermal stresses, Frequent Start and stops	Overheating, Ripple effect and increase in Total Harmonic distortion.
	Rotor mass unbalance	Shaft bending, Internal misalignment, Manufacturing defects	Dynamic eccentricity, increase in harmonic levels

Over-Voltage

An overvoltage occurs when the root mean square value of the voltage increases more than rated voltage level by 0.1 PU to 0.8 PU at power frequency for time ranging between half of a cycle to one minute.

Causes of Over-voltage

OV faults are less frequent compared to UV faults. But both arise because of system faults. LG fault may cause increase in the voltage of other phases leading to OV faults. When capacitor banks are switched on and heavy industrial loads are disconnected it give rise to OV fault. Floating point delta as well as ungrounded systems suffers from this fault where ground reference exchange leads to rise in the voltage [09], [10].

However, connecting capacitor banks is major reason behind OV fault. But because of disconnection of heavy load current reduces suddenly causing increase in the voltage. Effects of OV are very severe as high voltage may lead to heating or even burning of electronic equipment as sensitive equipment can easily be affected by this rise in the voltage.

Some more causes of Overvoltage are given below:

- Loss of a Secondary Neutral (When the neutral wire is broken by falling branches).
- Ferro resonance (is a form of series resonance between system charging capacitance and the magnetizing reactance of the transformer)
- Accidental Contact to High-Voltage Circuits

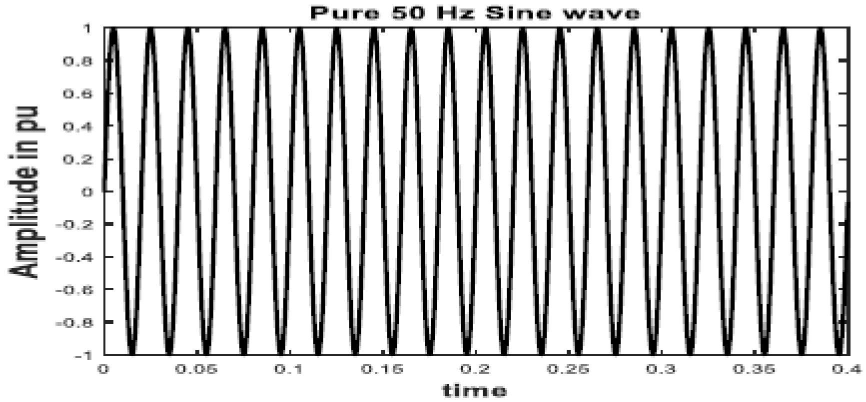
Ferro resonance, high voltage circuit contact, lightning transformer and machines.

Single Phasing Broken or loose or oxidized terminal contact, melting of fuse Melting of insulation,overloading of generators, increase in, vibrations and noise of motors, damage to motor winding, fluctuations in torque.

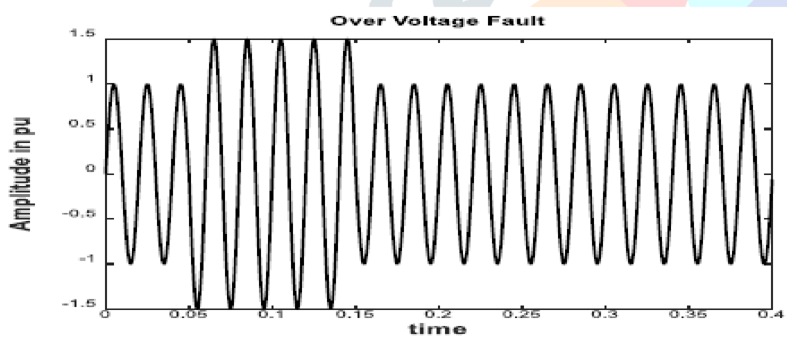
Voltage Unbalance Difference in reactance of the phases, connecting heavy loads to one of the phase, Reduction in efficiency of the motor, heating, melting of grease of bearings, excessive vibrations, increase in copper losses.

 Over voltages Due to Poor Voltage Regulation

Waveform for Single Phase Healthy Motor



Over Voltage Fault



Classification Techniques

SVM Kernel Functions

SVM algorithms use a set of mathematical functions that are defined as the kernel. The work of the kernel function is to take the input data and transform that data into the required form of infinite dimension feature space. The types of kernels [51] [50] used for SVM are:

 Linear kernels

$$k(x, x') = xTx'$$

 Gaussian radial basis kernels

$$k(x, x') = \exp\ (-||x - x'||22\sigma 2\ )\ for\ \sigma > 0$$

 Sigmoid kernel

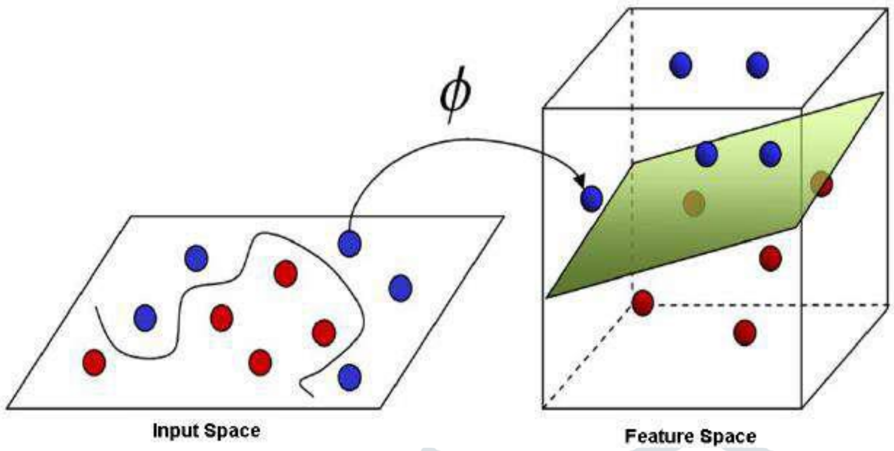
$$k(x, x') = \tanh(\alpha xTx' + c)$$

 Polynomial kernels

$$k(x, x') = (\ 1 + xTx')d\ for\ any\ d > 0$$

Contains all polynomials terms up to degree d

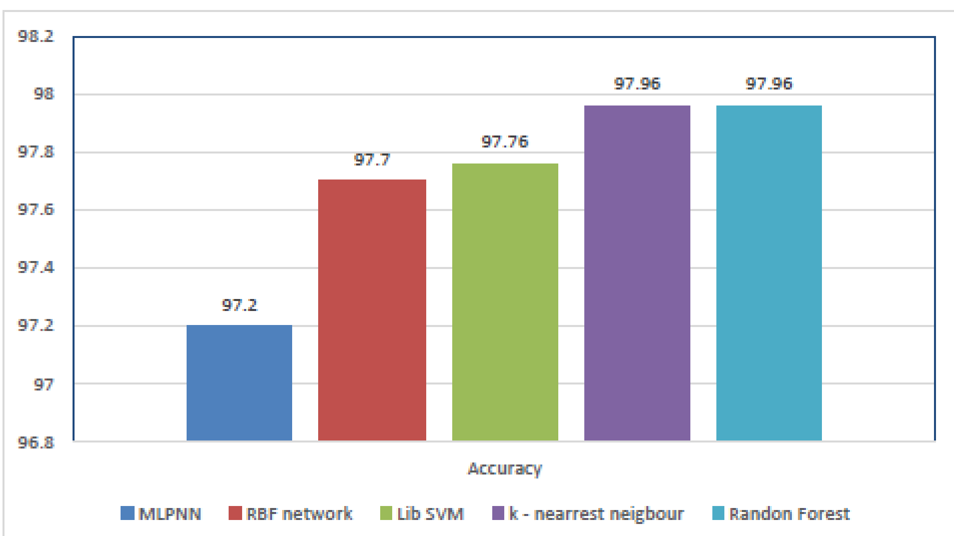
Transferring Input Space to Feature Space for SVM



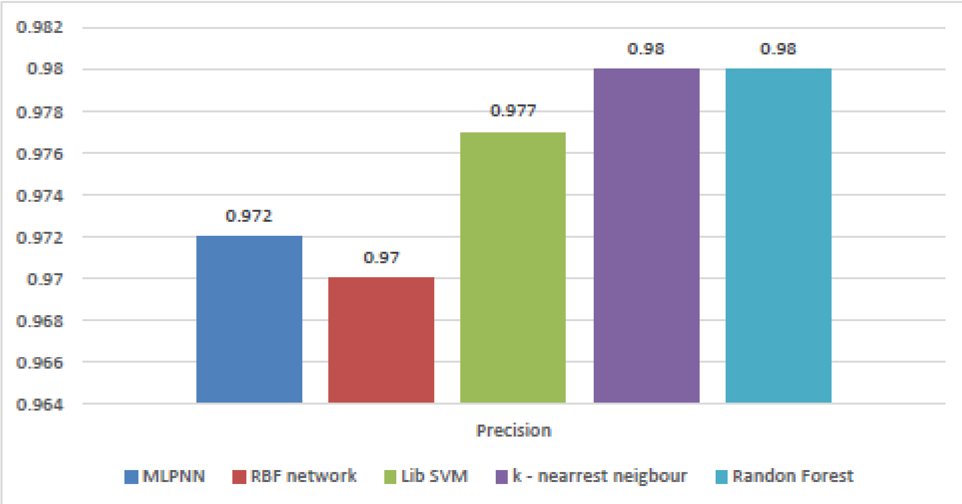
Result & Discussion

In this work the detection of external faults has been done and the comparison of all of the techniques has been illustrated in Figure below Comparison of accuracy for external fault detection, Figure below Comparison of Precision for external fault detection and Figure below Comparison of relative absolute error for external fault detection

Comparison of accuracy for external fault detection



Comparison of Precision for external fault detection



From the analysis it can be seen that for the detection of external faults, Random Forest is best suited as it provides best accuracy and precision with least relative absolute error. For the internal fault detection from the analysis it can be concluded that S – Transform provides best fault detection as compared to DFT, Envelope Analysis and Statistical Analysis.

Conclusion

In this work various fault detection techniques have been implemented for the detection of internal and external faults. As in motor number of faults can be present for that the multiple fault detection has been discussed. The external faults include UV, OV, OL, SP and VUB faults. The detection of these faults has been done by using MLPNN, RBFN, KNN, SVM and Random Forest. From the results it can be concluded that for the external fault detection random forest provides best results as it gives high accuracy and precision with low relative absolute error compared to other techniques. For the internal fault detection, bearing fault detection has been implemented. It has been seen that if the amplitude of the fault is low then FFT is unable to detect the fault as it can be mistaken as noise. So, a better algorithm as Envelope analysis is done it provides fault detection with more accuracy. Statistical analysis provides fault detection as the RMS to Maximum peak of healthy motor and faulty data falls at different locations and the fault can be detected as it has high RMS and high peak to peak amplitude as compared to healthy motor. In the S – Transform it can be seen that new fault frequencies are present and that signifies the fault. It can be concluded that S– Transform provides more accuracy for the detection of faults.

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