DATA BEHOLDING AND FAULT DIAGNOSIS OF SQUIRRAL CAGE INDUCTION MOTOR

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ABSTRACT

The condition beholding of induction motor has been a challenging task for the engineers and researchers mainly in industries. There are many methods in condition beholding, including vibration beholding, thermal beholding, chemical beholding, acoustic emission beholding but, all these beholding methods require expensive sensors or specialized tools whereas current beholding out of all does not require additional sensors. Current beholding techniques are usually applied to track the various types of induction motor faults such as rotor fault, short winding fault, air gap eccentricity fault, bearing fault, load fault etc. In current beholding, no additional sensors are necessary. This is because the completely necessary electrical quantities related to electromechanical plants like current and voltage are readily measured by tapping into the prevailing voltage and current transformers that are always installed as a part of the protection system. As a current beholding is non-invasive and may even be implemented in the motor control centre remotely from the motors being monitored The MCSA uses the current spectrum of the machine for locating characteristic fault frequencies. When a fault is present, the frequency spectrum of the road current becomes different from healthy motor. Such fault modulates the air-gap and produces rotating frequency harmonics within the self and mutual inductances of the machine. It depends upon locating specific harmonic component within the line current.[2]

An extensive literature survey has been finished understanding the varied faults and signal processing techniques available. It was observed that fault frequencies occur within the motor current spectra are unique for various motor faults. These fault frequencies can be easily tracked with help of Motor Current Signature analysis (MCSA). Therefore, MCSA based techniques are used to present work for diagnosis of the common faults of induction motor.

There are three type of Fourier transform, such as Fast Fourier Transform algorithm (FFT), Short Time Fourier transform algorithm and Wavelet Transform based multi resolution analysis algorithm. FFT Method is easy to implement. More interesting signals contain numerous transitory characteristics like drift, trends, and abrupt changes. These characteristics are often the most important part of the signal, and the Fourier analysis is not suitable for their diagnosis. Therefore, other methods for signal analysis, such as STFT, Wavelet transform are subsequently used to track the rotor faults experimentally.[1]

Keyword : - *MCSA, CONDITION BEHOLDING*

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1. INTRODUCTION

he studies of induction motor behavior during abnormal conditions thanks to the presence of faults and therefore the possibilities to diagnose these abnormal conditions are a challenging topic for several electrical machine researchers. There are many conditions beholding methods, including vibration beholding, thermal beholding, chemical beholding, acoustic emission beholding but of these beholding methods require expensive sensors or specialized tools whereas current beholding out of all doesn't require additional sensors. This is often because the essential electrical quantities related to electromechanical plants like current and voltage are readily measured by tapping into the prevailing voltage and current transformers that are always installed as a part of the protection system. As a result, current beholding is non-intrusive and should even be implemented within the control centre remotely from the motors being monitored.[1]

It is observed that the technique called Motor Current Signature Analysis (MCSA) is predicated on current beholding of induction motor; therefore, it's not very expensive. The MCSA uses the present spectrum of the machine for locating characteristic fault frequencies. When a fault is present, the frequency spectrum of the road current becomes different from healthy motor, it offers significant implementation and economic benefits Motor Current Signature Analysis (MCSA) based methods are wont to diagnose the common faults of induction motor like broken bar fault, short winding fault, bearing fault, air gap eccentricity fault, and cargo faults the consequences of varied faults on current spectrum of an induction motor are investigated through experiments.[2]

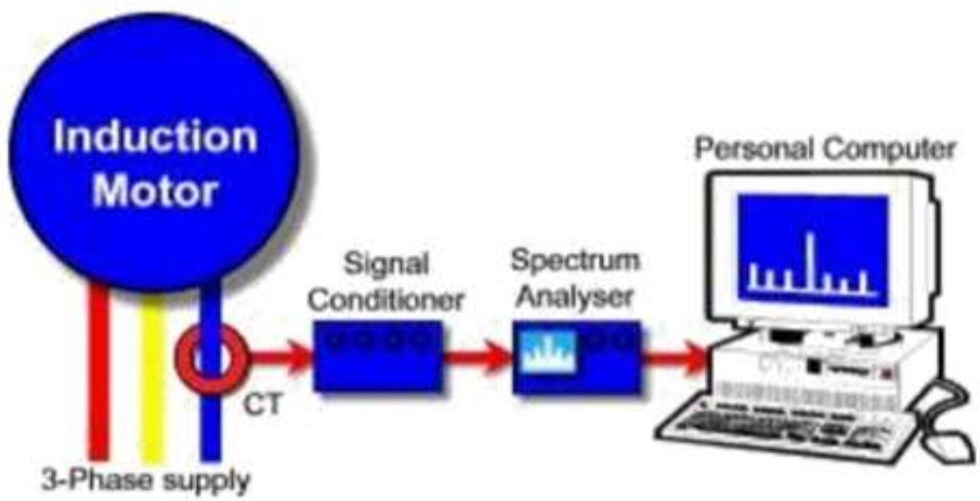

Fig. 1. MCSA overview

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The various advanced signal processing techniques like Fast Fourier Transform, Short Time Fourier Transform, Gabor Transform, and Wavelet Transform want to diagnose the faults of induction motor. A suitability of the signal for various sorts of faults is additionally discussed intimately. FFT is straightforward to implement, but the disadvantage of this system is that it's not suitable for analyzing transient signals. Although Short-Time Fourier Transform (STFT) are often used for analyzing transient signals employing a time-frequency representation, but it can only analyze the signal with a hard and fast sized window for all frequencies, which results in poor frequency resolution. However, Wavelet Transform can overcome this problem by employing a variable sized window.[3]

In order to perform accurate and reliable analysis on induction motors, the installation of the motors and measurement of signal got to be accurate. Therefore, a procedure and an experimental found out has been designed which will accurately repeat the measurements of signals and may introduce a specific fault to the motor in isolation of other faults.

The signal processing techniques have advantages that these aren't computationally expensive, and these are simple to implement. Therefore, fault detection supported, the signal processing techniques are suitable for an automatic on-line condition beholding system. Signal processing techniques usually analyze and compare the magnitude of the fault frequency components, where the magnitude tends to extend because the severity of the fault increases. Therefore, the variance signal processing techniques are utilized in the present work for detection of the common faults of induction motor. Signal processing techniques have their limitations. For instance, the reliability of detecting the rotor fault using Fast Fourier Transform (FFT) depends on loading conditions and severity of faults. If the loading condition is just too low or the fault isn't too severe, Fast Fourier Transform may fail to spot the fault. Therefore, different techniques like Wavelet Transform (WT) investigated work to seek out better features for detecting common faults under different loading conditions.

The spread of faults can occur within three phase induction motors during the course of normal operation. These faults can cause a potentially catastrophic failure if undetected. Consequently, a spread of condition beholding techniques is developed for the analysis of abnormality. Signal processing techniques also are very effective for fault detection. Thanks to the continuous advancement of signal processing techniques and related instruments, online beholding with signal processing techniques has become very efficient and reliable for electrical machines. The target of this section is to present the classification of three phase induction motor faults and various advanced signal processing techniques for fault diagnosis of electrical machines.[2]

2. LITERATURE SURVEY

The literature review indicates that thermal beholding, vibration beholding, and electrical beholding, noise beholding, torque beholding and flux beholding are some important techniques of condition beholding and fault diagnosis of electrical Machines. In current beholding, no additional sensors are necessary. This is often because the essential electrical quantities related to electromechanical plants like currents and voltages are readily measured by tapping into the prevailing voltage and current transformers that are always installed as a part of the protection system. As a result, current beholding is non-intrusive and should even be implemented within the control center remotely from the motors being monitored. The Motor Current signature analysis (MCSA) and Current Park 's vector approach falls into current beholding. The MCSA is that the commonest sort of signal analysis technique utilized in electric beholding. In a literature review, it's been shown that there's a relationship between the mechanical vibration of a machine and therefore the magnitude of the stator current component at the corresponding harmonics. For increased mechanical vibrations, the magnitude of the corresponding stator current harmonic components also increases. This is often because the mechanical vibration modulates the air gap at that specific frequency. These frequency components then show up within the stator inductance, and eventually within the stator current. For this reason, the MCSA are often wont to detect rotor and bearing faults. Because the flux within the air gap is defined because the product of the winding magneto-motive force (MMF) and therefore the air-gap presence, variations in either of those will cause anomalies within the flux distribution. The changes within the winding MMF mainly depend upon the winding distribution. On the opposite hand, the air-gap presence depends on numerous effects including stator slots, out-of-round rotors, air-gap eccentricities caused by mechanical unbalance and misalignment, and mechanical shaft vibrations caused by bearing or load faults. MCSA detects changes during a machine 's presence by examining the present signals. It uses the present spectrum of the machine for locating characteristic fault frequencies. The spectrum could also be obtained employing a Fast Fourier Transformation (FFT) that's performed on the signal under analysis. The fault frequencies that occur within the motor current spectra are unique for various motor faults. This method is that the most ordinarily used method within the detection of common faults of induction motors.

a) Non-intrusive detection technique: With the technological advances in current-measuring devices, inexpensive and easy-to-use clamp-on probes are cheaper and convenient to use for sampling current without having to disconnect the circuit or to disassemble the equipment.

b) Remote sensing capability: Current sensors are often placed anywhere on the electrical supply route without jeopardizing the signal strength and performance.

c) Safe to operate: Since there's no physical contact between the present sensor and therefore the motor-driven equipment, this sort of beholding technique is especially attractive to applications where safety is of major concern. Wavelet Transform is often used for fault diagnosis of induction motor. It works on principle that each one signals are often reconstructed from sets of local signals of varying scale and amplitude, but constant shape. It's a simple and fast to implement processing technique. It analyses the signal at different frequency bands with different resolution by decomposing the signal into coarse approximation and detail information.

Current Park ‘s vector is most frequent used method in literature review applied to diagnose the common faults of induction motor. The analyses of the three-phase induction motor are often simplified using the Park transformation. the tactic is predicated on the visualization of the motor current Park ‘s vector representation. If are often” this is often an ideal circle the machine can be considered as healthy if an elliptical pattern is observed for this representation, the machine is faulty from the characteristics of the ellipse the fault's type are often established. The elasticity increases with the severity of the fault. From the literature cited, the subsequent observations are often made:

(1) Condition beholding has great significance within the business environment because there's got to improve reliability of machine and to scale back the value of maintenance.

(2) The main disadvantage of vibration beholding is cost. A daily vibration sensor costs several hundred dollars. A high product cost is often incurred just by employing the required vibration sensors for an outsized number of electrical machines. Another disadvantage of vibration beholding (Another disadvantage of vibration beholding is that it requires access to the machine.) is that it requires access to the machine. For accurate measurements, sensors should be mounted tightly on the electrical machines, and expertise is required within the mounting. On other hand, there's no physical contact between the present sensor and motor-driven equipment in electric beholding therefore electric beholding is especially attractive to applications where safety is of major concern.

(3) In current based fault detection, various sorts of faults may cause broadband changes in power spectra of stator current. Therefore, researchers choose the signal processing because the tool for stator current based fault detection.

(4) Investigations reveal that the fault frequencies occur in motor current spectra are unique for various motor faults.

(5) it's been a broadly accepted requirement that a diagnostic scheme should be non-invasive and capable of detecting faults accurately at low cost. Therefore, Motor

Current Signature Analysis {MCSA) has become a widely used method because its beholding parameter may be a motor terminal quantity that's easily accessible.

(6) Numerous applications of using electric beholding in motor health beholding are published among the nuclear-generation, industrial, defines industries. In published work, researchers used the variability of motors of various rating to diagnose the faults. But little or no work has been done to diagnose the all possible normal fault of induction motor by using the motor of same rating and same signal processing technique. So, there's got to use an equivalent sort of motor and same signal processing technique to diagnose common faults of induction motor in order that effectiveness of signal processing techniques is often studied.

(7) It is observed that only a few experimental studies are published which can diagnose the only fault of induction motors with sort of signal processing techniques. Therefore, an experimental study must be conducted to diagnose the only fault with different signal processing techniques in order that limitation of every signal processing technique is often studied.

(8) The effectiveness of signal processing techniques for non-stationary signals has not been addressed appropriately within the literature. Therefore, more experiments got to be administered with different signal processing techniques in order that it's going to be examined which technique is best fitted to non-stationary signals. [1]

3. Electrical faults

A. Rotor faults –

Usually the lower rating machines are manufactured by die casting (a metal casting process that is characterized by forcing molten metal under high pressure into a mold cavity) technique whereas the copper rotor bar is manufactured with high ratings machines. Several related technological problems can rise thanks to manufacturing of rotors by die casting techniques. It’s been found that cage induction motors show asymmetries within the rotor thanks to technological difficulties, or melting of bars and end rings. However, failures can also end in rotors due to numerous other reasons. There are several main reasons of rotor faults.

• During the brazing process in the manufacture, non- uniform metallurgical stresses could also be built into cage assembly and these also can cause failure during operation.

• A rotor bar could also be unable to makeover longitudinally within the slot it occupies, when thermal stresses are imposed upon it during starting of the machine.

• Heavy end ring may result in large centrifugal forces, which may cause dangerous stresses on the bars.[8]

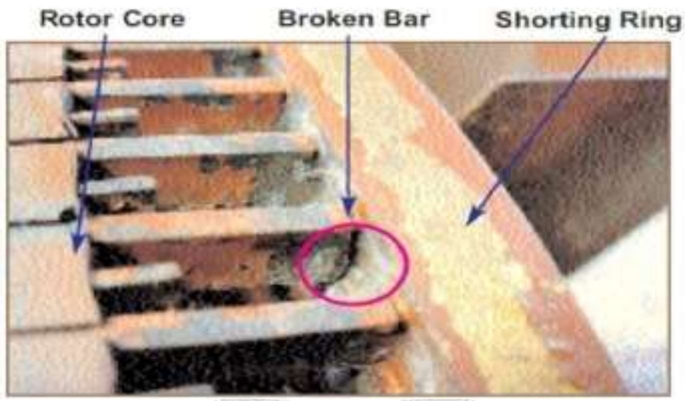


Fig .2.Broken rotor bar

Because of the above reasons, rotor bar could also be damaged and simultaneously unbalance rotor situation may occur. Rotor cage asymmetry leads to the asymmetrical distribution of the rotor currents. Thanks to this, damage of the one rotor bar can cause the damage of surrounding bars and thus damage can spread, resulting in multiple bar fractures. Just in case of a crack, which occurs during a bar, the cracked bar will overheat, and this will cause the bar to interrupt. Thus, the encompassing bar will carry higher currents and thus they're subjected to even larger thermal and mechanical stresses which can also start to crack. Most of the present which might have flowed within the broken bar now will flow within the two bars adjacent thereto. Thus, the massive thermal stresses can also damage the rotor laminations. The temperature distribution across the rotor lamination is additionally changed thanks to the rotor asymmetry. The cracking of the bar is often presented at various locations, including the slot portion of the bars into account and end rings of bar joints. The likelihood of cracking within the region of the top rings of bar joints is that the greatest when the start-up time of the machine is long and when frequent starts are required.[1]

A. Short turn fault

According to the survey, 35-40 you look after induction motor failures are associated with the stator winding insulation. Moreover, it's generally believed that an outsized portion of stator winding-related failures (Different types of stator winding faults that may develop are short circuit faults - (i) between turn to turn within a coil, (ii) between coil to coil of the same phase, (iii) between phase to phase, (iv) phase to earth and (v) open circuit fault) are initiated by insulation failures in several turns of a stator within one phase. This sort of fault is referred as a stator turn fault. A stator turn fault during a symmetrical three-phase AC machine causes an outsized circulating current to flow and subsequently generates excessive heat within the shorted turns. If the warmth which is proportional to the square of the circulating current exceeds the limiting value the entire motor failure may occur. However, the worst consequence of a stator turn fault could also be a significant accident involving loss of human life. The organic materials used for insulation in electric machines are subjected to deterioration from a mixture of thermal overloading and cycling, transient voltage stresses on the insulant, mechanical stresses, and contaminations. Among the possible causes, thermal stresses are the most reason for the degradation of the stator winding insulation. Stator winding insulation, thermal stresses (thermal stress is mechanical stress created by any change in temperature of a material) are categorized into three types: aging, overloading, and cycling. Even the simplest insulation may fail quickly if the motor is operated above its temperature limit. As a rule of thumb, the lifetime of insulation is reduced by 50 you take care of every 100C increase above the stator winding temperature limit. It’s thus necessary to watch the stator winding temperature in order that an electrical machine won't operate beyond its thermal capacity. For this purpose, many techniques are reported. However, the inherent limitation of those techniques is their inability to detect a localized hot spot at its initial stage. A couple of mechanical problems that accelerate insulation degradation include movement of a coil, vibration resulting from rotor unbalance, loose or worn bearings, air gap eccentricity, and broken rotor bars. The present within the stator winding produces a force on the coils that's proportional to the square of the present. This force is at its maximum under transient overloads, causing the coils to vibrate at twice the synchronous frequency with movement in both the radial and therefore the tangential direction. This movement weakens the integrity of the insulation system. Mechanical faults, like broken rotor bar, worn bearings, and air-gap eccentricity, could also be a reason why the rotor strikes the stator windings. Therefore, such mechanical failures (failure due to a defect in materials or workmanship) should be detected before they fail the stator winding insulation. Contaminations thanks to foreign materials can cause adverse effects on the stator winding insulation. The presence of foreign material can cause a discount in cooling it's thus vital to stay the motors clean and dry, especially when the motors operate during a hostile environment.[4]

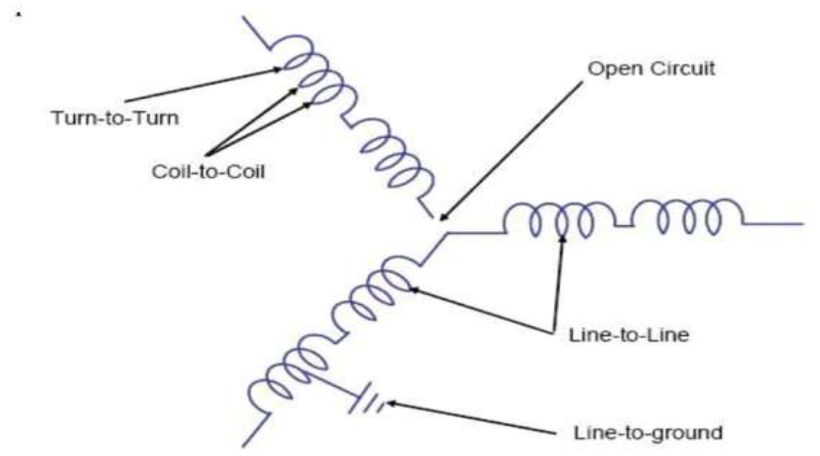


Fig . 3.Various types of winding fault

Regardless of the causes, stator winding-related failures are often divided into the five groups: turn-to-turn, coil-to-coil, line-to-line, line-to-ground, and open-circuit faults as presented. Among the five failure modes, turn-to-turn faults (stator turn fault) are considered the foremost challenging one since the opposite sorts of failures is usually the results of turn faults. Furthermore, turn faults are very difficult to detect at their initial stages to unravel the problem in detecting turn faults, many methods are developed.[5]

4.MECHANICAL FAULT

A. Air gap quirk:

Air gap quirk is common rotor fault of induction machines. This fault produces the issues of vibration and noise. during a healthy machine, the rotor is center-aligned with the stator bore, and therefore the rotor 's center of rotation is that the same because the geometric center of the stator bore. When the rotor isn't center aligned, the unbalanced radial forces (unbalanced magnetic pull or UMP) can cause a stator-to-rotor rub, which may end in damage to the stator and therefore the rotor. There are three sorts of air gap quirk:

1) Static quirk

2) Dynamic quirks

3) Mixed quirk

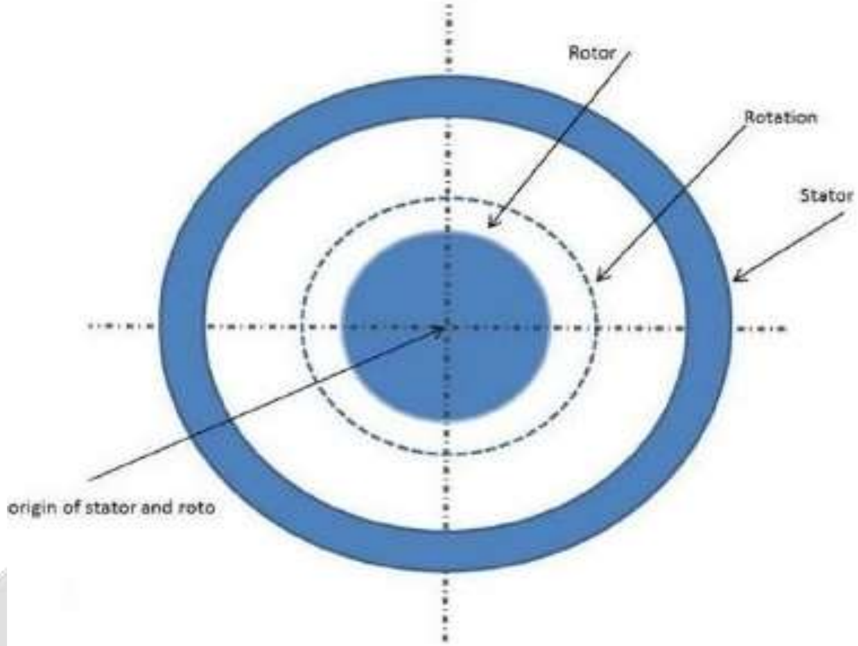


Fig.4. Healthy model

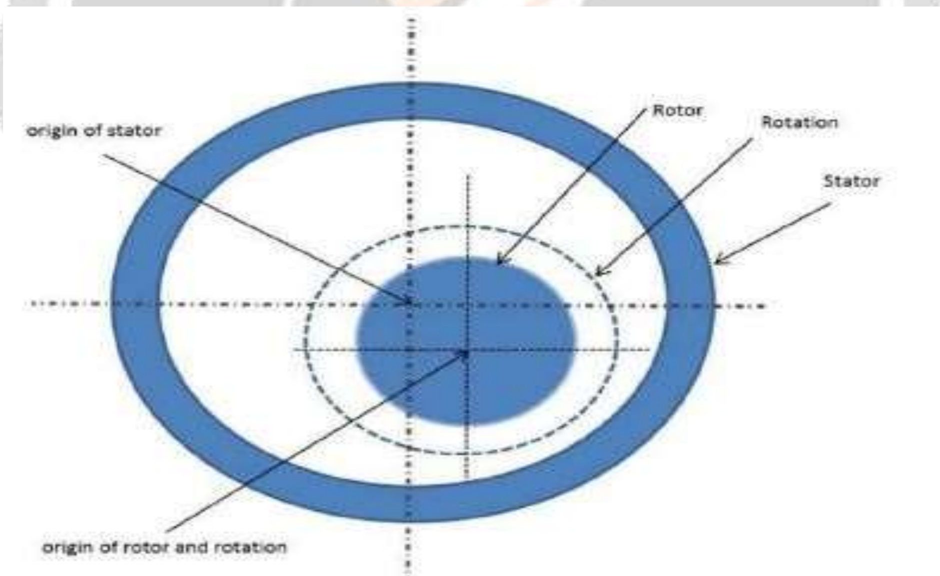


Fig.5.Static model

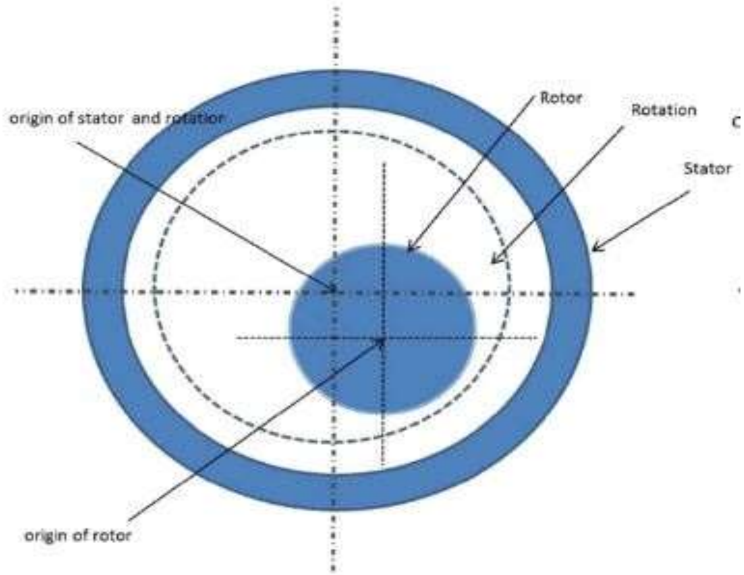


Fig.6.Daynamic model

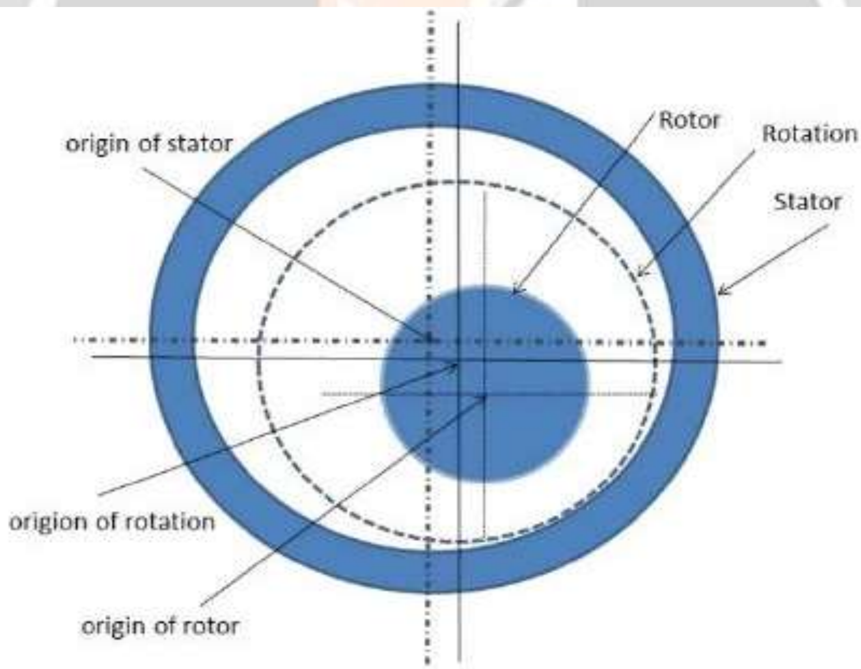


Fig.7.Mixed model

Static quirk may be a steady pull in one direction which creates UMP. It’s difficult to detect unless special equipment is employed. 24 A dynamic quirks on the opposite hand produce a UMP that rotates at the rotational speed of the motor and acts directly on the rotor. This makes the UMP during a dynamic quirk easier to detect by vibration or current beholding. Actually, static and dynamic eccentricities tend to coexist. Ideal centric conditions can never be assumed. Therefore, an inherent grade of quirk is implied for any real machine. The combined static and dynamic quirk is known as mixed quirk.[5]

A. Bearing faults:

Bearings are common elements of electrical machine. They're employed to permit rotation of the shafts. In fact, bearings are single largest explanation for machine failures. Consistent with some statistical data, bearing fault account for over 41% of all motor failures. Bearing consists of two rings called the inner and thus the outer rings. a group of balls or rolling elements placed in raceways rotate inside these rings. A continued stress on the bearings causes fatigue failures, (Deformation of a material at repeated stresses) usually at the inner or outer races of the bearings. Small pieces break loose from the bearing, called flaking or spelling. These failures end in rough running of the bearings that generates detectable vibrations and increased noise levels. This process is helped 25 by other external sources, including contamination, corrosion, improper lubrication, improper installation, and brandling. The shaft voltages and currents also are sources for bearing failures. These shaft voltages and currents result from flux disturbances like rotor eccentricities. High bearing temperature is one more reason for bearing failure. Bearing temperature shouldn't exceed certain levels at rated condition for instance, within the petroleum and industry, the IEEE 841 standard specifies that the stabilized bearing temperature rise at rated load shouldn't exceed 45 degree. The bearing temperature rises are often caused by degradation of the grease or the bearing. The factors which can cause the bearing temperature rise include winding temperature rise, motor operating speed, temperature distribution within motor, etc.[6]

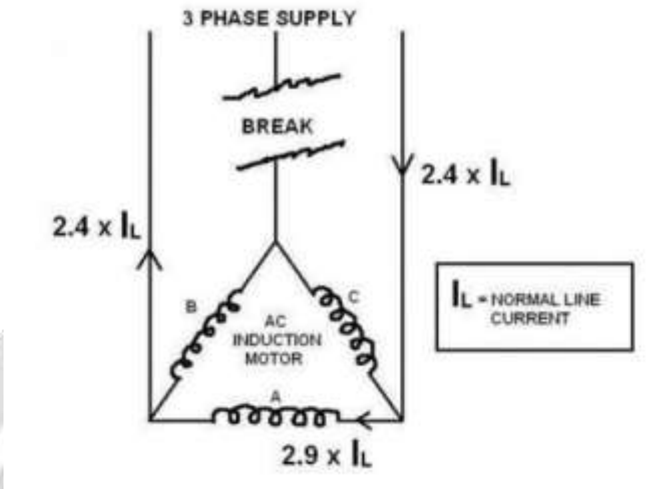
A fault in bearing might be imagined as a little hole, a pit or a missing piece of fabric on the corresponding elements. Under normal operating conditions of balanced load and an honest alignment, fatigue failure begins with small fissures, located between the surface of the raceway and rolling elements, which gradually propagate (the spreading of something) to the surface generating detectable vibrations and increasing noise levels. Continued stress causes fragments of the fabric to interrupt loose, producing localized fatigue phenomena referred to as flaking or spelling. Once started, the affected area expands rapidly contamination the lubricant and causing localized overloading over the whole circumference of the raceway. Some sources like contamination, corrosion, improper lubrication, improper installation or brandling reduce the bearing life. Contamination and corrosion are the key factors of bearing failure due to the tough environments present in most industrial settings. The lubricants are contaminated by dirt and other foreign matter that are commonly often present within the environment of industries. Bearing corrosion is produced by the presence of water, acids, deteriorated lubrication (the action of making a process run smoothly) and even perspiration from careless handling during installations. Once the reaction has advanced sufficiently, particles are worn-off resulting in the same abrasive action produced by bearing contamination. Under and over-lubrication are also another causes of bearing failure. In either case, the rolling elements aren't allowed to rotate on the designed oil film causing increased levels of heating. The excessive heating causes the grease to interrupt down, which reduces its ability to lubricate the bearing elements and accelerates the failure process. Additionally, Installation problems are often caused by improperly forcing the bearing onto the 26 shaft or within the housing. This produces physical damage in sort of brandling or false brandling of the raceways which results in premature failure. Brandling is that the formation of indentations within the raceways as a results of deformation caused by static overloading. While this sort of injury is rare, a kind of ―false brandling‖ occurs more often. Misalignment of the bearing is additionally a standard result of defective bearing installation. No matter the failure mechanism, defective rolling element bearings generate mechanical vibrations at the rotational speeds of each component. Imagine for a hole on the outer raceway: as rolling elements give way the defect, they're regularly in touch with the opening which produces an impact on the machine at a given frequency. Thus, these characteristic frequencies are associated with the raceways and therefore the balls or rollers, are often calculated from the bearing dimensions and therefore the rotational speed of the machine.[8]

B. Load Faults:

In some applications like aircrafts, the reliability of gears could even be critical in safeguarding human lives. For this reason, the detection of load faults (especially related to gears) has been an important research area in engineering for a couple of time. Several faults can occur during this mechanical arrangement. Samples of such faults are coupling misalignments and faulty gear systems that couple a load to the motor.

C. Single phasing:

Single phasing is a condition in three phase motors and transformers wherein the supply to one of the phases is cut off. Since, motors generally have low impedances for negative phase sequence voltage. The distortion in terms of negative phase sequence current will be substantial. Negative phase sequence currents cause heating of the motor and consequently motor failure. Single phasing is caused by the use of single-phase protection devices such as 27 fuses and circuit breakers. Defective contacts in three phase breakers can also cause single phasing. Motor protection relays for larger motors come readily (quickly or easily) fitted with protection against single phasing. Single phasing can sometimes cause excessive (extreme mean going beyond a normal limit) noise and vibration in motors.[7]



5. CONCLUSIONS

Industrial case histories have clearly demonstrated that MCSA may be a powerful online beholding technique for assessing the operational condition of three-phase induction motors. The avoidance of catastrophic failures is often achieved via MCSA and other major benefits includes the prevention of lost downtime, avoidance of major motor repair, or replacement costs In fact rock bottom line is that the prevention of lost income being the key driver for using MCSA to assess the operational condition of strategic induction motor drives. The importance of applying induction motor fundamentals, understanding signal processing concepts, paying particular attention to detail when taking MCSA measurements to make sure reliable data, appreciating the operational conditions of the motor, and, of course, correct interpretation of the info are illustrated during this project. It's emphasized that knowledge on the planning and operation of induction motors are crucial ingredients for proper data interpretation and a reliable diagnosis of the operational condition of the motor. Experiment and simulation results showed the efficiency of the proposed method to identify and discriminate between the various faults, but the main drawback of this method is within the case of sunshine loaded or unloaded machines, it's difficult to detect faults and fortunately an IM operates most the time under its rated load torque.[1]

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