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ANALYSIS OF HARMONICS USING CSA TECHNIQUE IN INDUCTION MOTOR

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ABSTRACT

Computer simulation of an electric motor operation is particularly useful for gaining an insight into their dynamic behaviour and electromechanical interaction. A suitable model that we developed enables motor fault to be simulated and the change in corresponding parameter to be predicted without physical experimentation. This paper presents both theoretical and experimental current signature analysis of three-phase induction motor on the benchmark of harmonics. In this work faults are manually introduced and cleared into the motor and monitor the machine for stator current during occurring and clearing of fault. This paper also assesses the severities of fault and can be useful for comparing the results of faulty induction motor.

KEYWORDS: CSA-Current Signature Analysis.

I. INTRODUCTION

Electrical machines have been used extensively for many different industrial applications since several decades ago. These applications range from intensive care unit pumps, electric vehicle propulsion systems, and computer-cooling fans to electric pumps used in nuclear power plants. The electrical energy that is consumed in (induction) motors accounts for around 60% of the electrical energy that is consumed by industry in developed economies [1].The present-day requirement for the ever-increasing reliability of electrical machines is now more important than ever before and continues to grow. Advances are continually being made in this area as a result of the consistent demand from the power generation and transportation industries. Because of the progress made in engineering and materials science, rotating machinery is becoming faster and lighter, as well as being required to run for longer periods of time. All of these factors mean that the detection, location, and analysis of faults play a vital role in the good operation of the electrical machine and are essential for major concerns such as the safety, reliability, efficiency, and performance of applications involving electrical machines. Although continual improvement in design and manufacturing has become a priority task among contemporary manufacturers of electrical machines, faults still can and do occur.

II. FAULTS IN ELECTRICAL MACHINES

A fault in a component is usually defined as a condition of reduced capability related to specified minimal requirements and is the result of normal wear, poor specification or design, poor mounting (including poor alignment), wrong use, or a combination of these. If a fault is not detected or if it is allowed to develop further it may lead to a failure [2].Several surveys have been carried out on the reliability of electrical machines. In such surveys, a large number of machine operators were usually questioned on the types and frequency of faults occurring in their plant. The largest of these surveys, carried out by the General Electric Company, was reported in an EPRI (Electric Power Research Institute) publication (1982) and covered about 5000 motors, approximately 97% of which were three phase cage induction motors. According to this survey, figure below presents the distribution of faults occurring in the motors surveyed.

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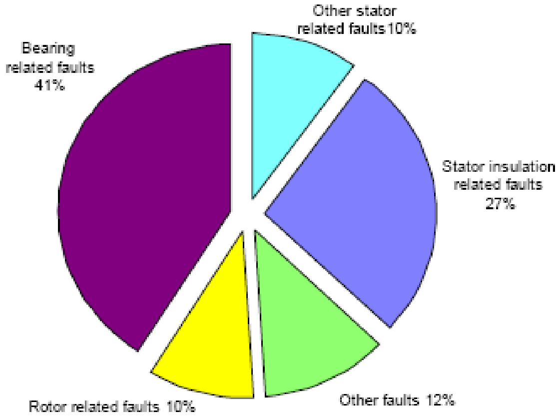

Fig1: Different faults in Induction motor

The major faults of electrical machines can broadly be classified as a) Stator faults resulting in the opening or shorting of one or more of a stator phase winding, b) Abnormal connection of the stator windings, c) Broken rotor bar or cracked rotor end-rings, d) Static and /or dynamic air-gap irregularities, e) Bent shaft (akin to dynamic eccentricity) which can result in a rub between the rotor and stator, causing serious damage to stator core and windings, f) Shorted rotor field winding , and g) Bearing and gearbox failures. These faults produce one or more of the symptoms as a) Unbalanced air-gap voltages and line currents, b) Increased torque pulsations, c) Decreased average torque, d) Increased losses and reduction in efficiency, and e) Excessive heating.

(a) Bearing Faults

Porosity is more common in cast rotors and is one of those defects that are invisible to the naked eye. Rotor porosity, which causes imbalances in the rotor field, will develop into high vibrations commonly resulting in bearing damage. The majority of electrical machines use ball or rolling element bearings and these are one of the most common causes of failure. These bearings consist of an inner and outer ring with a set of balls or rolling elements placed in raceways rotating inside these rings. Faults in the inner raceway, outer raceway or rolling elements will produce unique frequency components in the measured machine vibration and other sensor signals. These bearing fault frequencies are functions of the bearing geometry and the running speed [7]. Bearing faults can also cause rotor eccentricity [9].

(b) Stator Faults

Almost 40% of all reported induction machine failures fall into this category. The stator winding consists of coils of insulated copper wire placed in the stator slots. The most of the stator related faults are due to degraded insulation in stator windings causing an inter-turn, phase-to-phase or phase-to-ground short circuits. These are serious faults that result in a complete machine failure. The resultant induced currents produce extra heating and cause an imbalance in the magnetic field in the machine. If undetected, the local heating will cause further damage to the stator insulation until catastrophic failure occurs. The unbalanced magnetic field can also result in excessive vibration that can cause premature bearing failures.

(c) Rotor Faults

Rotor faults account for about 10% of total induction machine failures. The normal failure mechanism is a breakage or cracking of the rotor bars where they join the end-rings which can be due to thermal or mechanical cycling of the rotor during operation. This type of fault creates the well-known twice slip frequency sidebands in the current spectrum around the supply frequency signal.[12]

(d) Other Faults

Eccentricity occurs when the rotor is not centered within the stator, producing a non-uniform air gap between them. This can be caused by defective bearings or manufacturing faults. The variation in air gap disturbs the magnetic field distribution within the motor which produces a net magnetic force on the rotor in the direction of the smallest air gap. This so called "unbalanced magnetic pull" can cause mechanical vibration.

III. CURRENT SIGNATURE ANALYSIS (CSA)

During last years, MCSA has been widely studied in addition to vibration analysis for induction motor fault detection. It has been claimed that electrical measures contain the same information on the faults of motor as the vibration measurement [8]. The main benefit of using motor current as the basis of fault detection system instead of vibrations is that no extra instrumentation is needed for measurements. In particular, a large amount of research has been directed towards detecting broken rotor bars and mechanical unbalance from the spectrum of stator current. This is an ironic fact, because the rotor related faults are actually quite rare compared to e.g. bearing faults. However, in many cases these specific faults can be quite easily detected from characteristic frequencies of the stator current. The traditional way to produce the current signature is the calculation of frequency spectrum with an FFT based method, but in addition to this there exist various model-based MCSA fault diagnostics systems can be found in literature. The sensitivity and robustness of the on-line model based Vienna monitoring method is addressed [13]. The method utilizes a voltage and a current model structure, which respond differently to the faulty rotor bar. Differences of the model outputs are evaluated and clustered. A NN based MCSA method can be found in [14], where an example of using NNs for modeling an induction motor is presented. There the faulted machine models used to formalize the knowledge base of the diagnostic system are formed with NNs.In [15], an interesting NN based clustering approach for fault diagnostics of an electrical machine is presented and NNs are used to learn on-line the spectral characteristics of a healthy motor current. A special frequency filter is used to pass only those harmonics, which are known to be of importance in fault detection, to a NN clustering algorithm.

Also, in MCSA, fuzzy logic has become common, especially, in the decision making part of the diagnostics scheme.[16], fuzzy logic is applied to induction motor condition monitoring and its stator and phase conditions through the amplitude features of the stator currents. Further, in [17], ANFIS (Adaptive Neuro Fuzzy Inference System) -based fault diagnostics system of an induction motor is compared with another adaptive neuro-fuzzy system FALCON (Fuzzy Adaptive Learning Control Network).

IV. PROPOSED MODEL USING CSA TECHNIQUE

This model presents the state of the art for different monitoring techniques based on motor current signature analysis (MCSA) that are used to detect and, eventually, localize different faults in electrical machines. Vibration measurements have historically been the foundation of most on-line condition Monitoring programs, but new techniques such as those involving spectral analysis of the Electric line current powering the motor are becoming of significant interest. The main problem concerning the monitoring methods based on, for instance, measurement of the rotor speed, vibration, and fluxes is that they are essentially invasive, requiring transducers to be fitted in or around the machine, with an obvious interruption to operation. Besides the increase in costs, the mounting of additional sensors is also a practical problem in terms of motor design and approval by the manufacturer, operator, or safety legislation authorities. Hence on the basis of current signature during the occurrence of faults and at the time of clearance of faults, the level of harmonics is compared using Matlab results.

Simulink Model

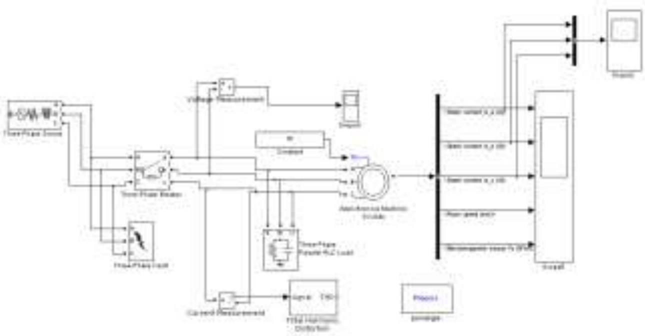

Fig 2: Three phase fault in Induction Motor Drive

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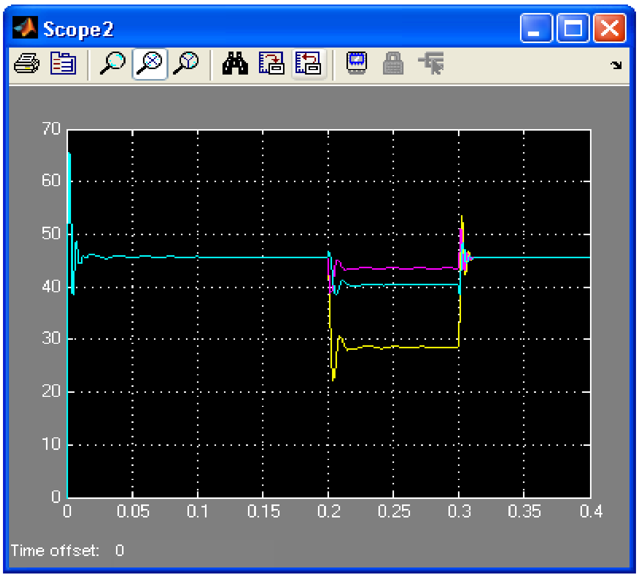

Fig 3:Line to Ground Fault

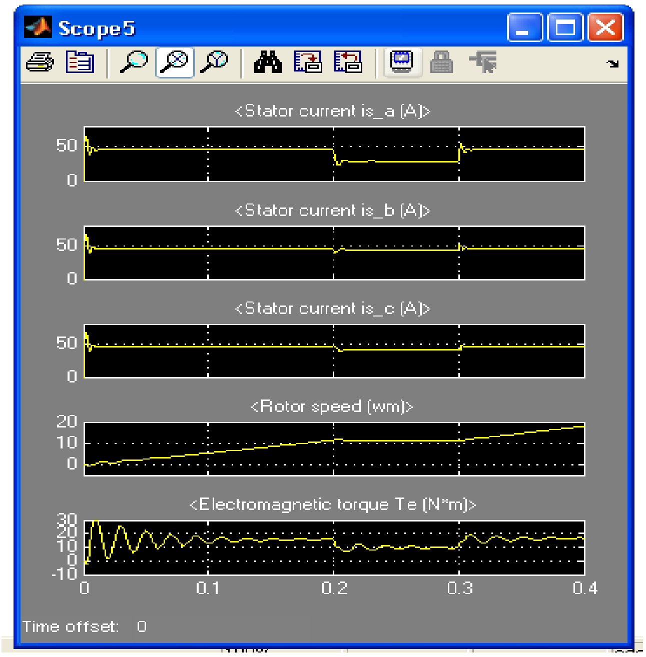

Fig4: Stator current analysis during fault

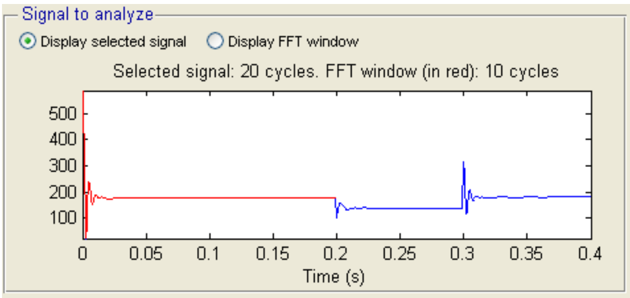

Fig5:FFT analysis of Fault current

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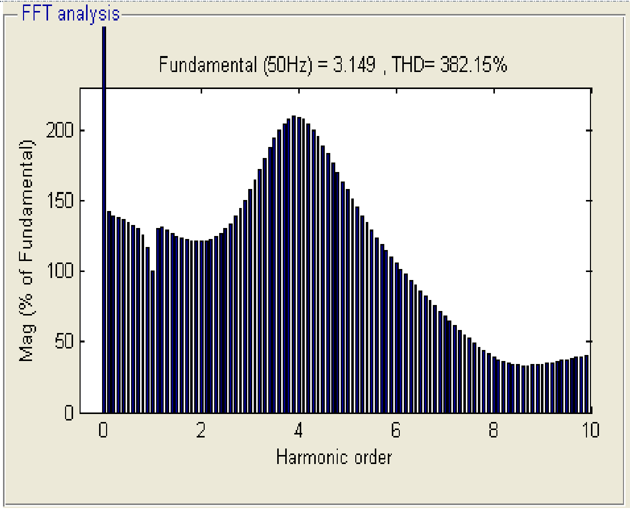

Fig6: Harmonics analysis during fault

V. RESULTS & CONCLUSION

1. **AG Fault**: Second, third and fourth harmonic amplitude is nearly same.
2. **BG Fault**: Fundamental component is larger than AG and CG Fault. Second, third and fourth harmonic amplitude is nearly same.
3. **CG Fault**: Second harmonic component is very high as compared to all three line-ground faults. Third and fourth harmonic amplitude are nearly same.
4. **ABG Fault**: Second, third and fourth harmonic amplitude is nearly same.
5. **BCG Fault**: Fourth harmonic is larger than third, third is larger than second. Fundamental component is larger than ABG and ACG Fault.
6. **ACG Fault**: Second harmonic component is high as compared to all three line-line-ground faults.
7. **ABCG Fault**: Second harmonic component is high as compared to third and fourth harmonic components.
8. **AB Fault**: Fundamental component is larger than AC. Second, third and fourth harmonic amplitude is nearly same.
9. **BC Fault**: Fundamental component is larger than AC. Second harmonic component is larger than third harmonic component and third harmonic component is larger than fourth harmonic component.
10. **AC Fault**: Fundamental component is smaller than AC and BC faults. Fourth harmonic is larger than third, third is larger than second.
11. **ABC Fault**: Second harmonic component is high as compared to third and fourth harmonic components.

Conclusion

Signature analysis should be carried out for all types of external and internal faults. As well as effect of these faults on other parameters such as temperature, life, reliability and quality of insulating material can be a futuristic extension to a integrated signature. Hence INTEGRATED SIGNATURE including electrical, thermal, mechanical and ambient characteristics should be known for machine/system. So that a versatile decision can be made regarding performance, life or health/risk involved with futuristic behaviour of machine/system. Building Condition Monitoring Institutions In foreign countries several different types of organizations oversee, operate, and participate in condition monitoring. These entities, some of which did not exist a few years ago, range from private companies to government agencies and include independent utilities.The fundamental entity responsible for maintaining condition monitoring as and when required on a real time basis should be formed in INDIA.

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