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Simulation of Stator Winding Fault of Three Phase Induction Motor using Motor Current Signature Analysis

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Abstract—*This paper presents the simulation of Stator winding inter-turn fault of three phase Induction motor through the current monitoring technique. Motor current signature analysis fall under current monitoring techniques. The Motor current signature monitoring (MCSA) uses the current spectrum of the machine for locating characteristic fault frequencies. When a fault is present, the frequency spectrum of the line current becomes different from healthy motor. MCSA detects changes in a machine's permeance by examining the current signals. It uses the current spectrum of the machine for locating characteristic fault frequencies. The spectrum is obtained using a Fast Fourier Transformation (FFT) that is performed on the signal under analysis. In the present research work, LabVIEW software is used to simulate the inter- turn stator winding faults of induction motor with direct online monitoring. The results illustrate good agreement between both simulated and experimental results.*

Keywords- *Induction motor, Motor Current Signature Analysis (MCSA), Fast fourier Tranformation (FFT), Stator winding inter-turn fault, LabVIEW*

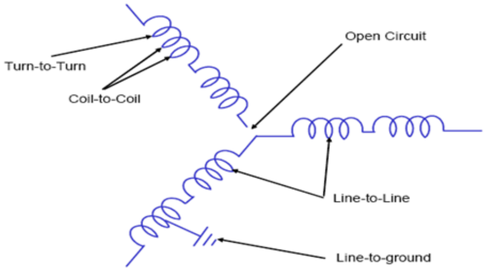
1. INTRODUCTION

A motor failure due to stator winding faults may result in the shutdown of a generating unit or production line. One major cause of the failures is breakdown of the winding insulation leading to puncture of ground wall. Early detection of stator short winding during motor operation may eliminate consequent damage to adjacent coils. It reduces repair cost and motor outage time.

In addition to the benefits gained from early detection of winding insulation breakdown, significant advantages may accrue by locating the faulted coil within the stator winding. The most common faults related to stator winding of induction motors are: phase-to-ground, phase-to-phase and short-circuit of coils of the same or different phase. According to the survey, 35-40% of induction motor failures are related to the stator winding insulation. Moreover, it is generally believed that a large portion of a stator coil within one phase. This type of fault is referred as a "stator turn fault". A stator turn fault in a symmetrical three phase AC machine causes a large circulation current to flown and subsequently generates excessive heat in the shorted turn. If the heat which is proportional to the square of the circulating current exceeds the limiting value the complete motor failure may occur. However, the worst consequence of a stator turn fault may be a serious accident involving loss of human life. The organic materials used for insulation in electric machines are subjected to deterioration from a combination of thermal overloading and cycling, transient voltage stresses on the insulating material, mechanical stresses and contaminations. Among the possible causes, thermal stresses are the main reason for the degradation of the stator winding insulation. Stator winding insulation thermal stresses are categorized into three types: aging, overloading and cycling. Even the best insulation may fail quickly if motor is operated above its temperature limit. As a rule of thumb, the life of insulation is reduced by 50% for every 10^0 C increase above the stator winding temperature so that an electrical machine will not operate beyond its thermal capacity. For this purpose, may technique has been reported. However, the inherent limitation of this technique is their inability to detect a localized hot spot at its initial stage.

A few mechanical problems that accelerate insulation degradation include movement of a coil, vibration resulting from rotor unbalance, loose or worn bearings, airgap eccentricity and broken rotor bars. The current in the stator winding produces a force on the coils that is proportional to the square of the current. 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 the tangential direction. This movement weakens the integrity of the insulation system. Mechanical faults, such as broken rotor bar, worn bearings, and airgap eccentricity, may be a reason why the rotor strikes the stator windings. Therefore, such mechanical failures should be detected before they fail the stator winding insulation. Contaminations due to foreign materials can lead to a reduction in heat dissipation. It is thus very important to keep the motors clean and dry, especially when the motors operate in a hostile environment.

Regardless of the causes, stator winding-related failures can be divided into the five groups: turn-to-turn, line-to-line, line-to-ground and open-circuit faults as presented in Fig. 1. Among the five failure modes, turn-to-turn faults (stator turn fault) have been considered the most challenging one since the other types of failures are usually the consequences of turn faults. Furthermore, turn faults are very difficult to detect at their initial stages. To solve the difficulty in detecting turn faults, this method has been developed.



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Short-circuit related faults have specific components in the stator current frequency spectrum (Eq. 1). Incipient fault can be detected by sampling the stator current and analyzing its spectrum.

The inter turn short circuit of the stator winding is the starting point of winding faults and it creates turn loss of phase winding. The short circuit current flows in the inter-turn short circuit windings. This initiates a negative MMF, which reduces net MMF of the motor phase. Therefore, the waveform of air gap flux, which is changed by the distortion of the net MMF, induces harmonic frequencies in the spectrum showing the presence of a short-circuit fault are given by the following equation.

$$f_{sc} = f_l \{ k \pm (n/p)(1-s)\} \qquad (1)$$

Where p is pole pairs, s is rotor slip, f_l is fundamental frequency in Hz, f_{sc} is the short-circuit related frequency in Hz, n is integer 1,2,3…..∞, k is 1,2,3,…∞.

The frequencies revealing the presence of short-circuit of winding are in some cases very close to frequencies related to other kinds of defect, as for example eccentricities. It is very important to distinguish one frequency from the other.

The MCSA is applied for detection of short winding fault where the side bands around the fundamental frequency indicate the stator winding fault in induction motor. Based on the MCSA, a system for fault detection was designed. The data acquisition card (PCI-6251) is used to acquire the current samples from the motor under load. The current signals are then transformed to the frequency domain using a power spectrum algorithm. The stator current is first sampled in the time domain and in the sequence; the frequency spectrum is calculated and analyzed aiming to detect specific fault frequencies related to incipient faults. For each short winding fault, there is an associated frequency that can be identified in the spectrum. Faults are detected comparing the harmonic amplitude of specific frequencies with the harmonic amplitude of the same machine considered as healthy. Based on the amplitude in dB it is also possible to determine the degree of faulty condition.

After reading the signal, it is decomposed by a Power spectrum algorithm. All the signal processing is performed using LabVIEW's 'Advance signal processing module' to generate the power spectrum. First motor was tested in the absence of fault. Afterwards, several experiments were performed on motor under no load and full load condition. Initially, the motor was damaged with 5% short circuit of winding. Then, severity of fault was increased to 15% and 30%. Table 1 show the severity of short winding faults and load conditions for various experiments conducted to diagnose the short winding fault.

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Experiments	Severity of short winding fault	Load condition
1	5% shortened	No load
2	15% shortened	No load
3	30% shortened	No load
4	5% shortened	Full load
5	15% shortened	Full load
6	30% shortened	Full load

2. OBSERVATION AND DISCUSSION

Experiments were conducted for healthy working condition and for winding short circuited 5%, 15% and 30%. During the test, the motor was coupled with rope brake dynamometer. The motor was operating at 0.7 Amp, corresponding to no load. It can be observed that the spectrum is completely free of faulted current components around main supply frequency. The motor thus shows no sign of stator winding faults. The experimental results for 5%, 15% and 30% short circuit of winding are given below:

2.1 5% short-circuit of winding

The power spectrum of faulty motor with 5%short circuit at no load is given in Fig. 3. The fault frequencies appear at 25 Hz and 75 Hz. At full load, fault frequencies appear at 27 Hz and 73 Hz as shown in Fig. 8. It is observed from Fig. 4 that at no load magnitude of fault frequency is -80 dB whereas at full load magnitude is -77 dB as shown in Fig. 8. It gives an indication that magnitude of fault frequency increases with increases in load. It is also observed from the figures that fault frequencies are clearly visible which indicates the short circuit winding fault in induction motor.

2.2 15% short-circuit of winding

The power spectrums of induction motor are also plotted for no load and full load operating condition with increased severity of fault (15%). The Fig. 5 shows the power spectrum of faulty motor with 15% short circuit of winding at no load. The fault frequency appear at 25 Hz and 75 Hz. It justifies the calculated and experimental results. The magnitude of fault frequency were found in between -77 dB and -75 dB for LSB and USB. Magnitude of fault frequencies has been increased if compared with magnitude of 5% severity of fault. Increases the magnitude of fault frequency with respect to increases in severity of fault is observed. Increase in magnitude of current component is undesirable aspect for the performance of induction machine. The same outcome has been observed for full load condition as shown in Fig. 7. The fault frequencies appear at 27 Hz and 73 Hz which is also a calculated value at full load condition. However, the magnitudes of these fault frequencies have been significantly increased due to increased loading condition and severity of fault.

2.3 30% short-circuit of winding

The severity of fault is increased by 30% and power spectrums for faulty motor for no load and full load conditions are shown in the Fig. 4 and 9 respectively. Virtual Instrument (VI) predicted the current components with increased magnitude which are obtained at position 25 Hz and 75 Hz for no load condition and 27 Hz and 73 Hz at full load condition. The components are distributed symmetrically around fundamental frequencies as expected. It is observed from the figures that the magnitudes of fault frequencies have been significantly increased up to -60 dB with increase of load and severity of fault.

The condition monitoring of the induction motor with help of Fast Fourier Transform (FFT) for finding the stator winding faults may give better results on line. Above observations can be summarized that with increase in load and percentage of short circuit winding the fault current magnitude increases. The fault frequencies obtained by mathematical derivation and experimentally are same for all the above cases. The complete observation from power spectrum analysis for short winding fault is given in Table 2.

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Fig. No.	**Short circuited stator winding**	**Load Condition**	**Table Column Head**				**Observations**
			Lower side band		***Upper side band***		
			FF	**Mag.**	**FF**	**Mag.**	
3	5%	No load	25 Hz	-80 dB	75 Hz	-80 dB	Visible
7	15%	Full load	27 Hz	-77 dB	73 Hz	-77 dB	Visible
4	30%	No load	25 Hz	-77 dB	75 Hz	-75 dB	Visible
8	5%	Full load	27 Hz	-72 dB	73 Hz	-72 dB	Visible
5	15%	No load	25 Hz	-71 dB	75 Hz	-62 dB	Visible
9	30%	Full load	27 Hz	-60 dB	73 Hz	-60 dB	Visible

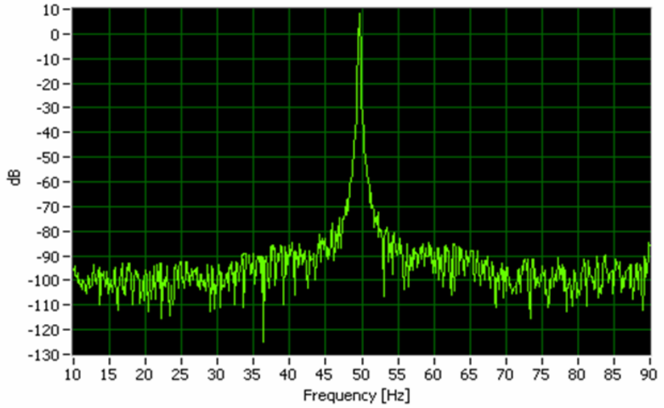

Fig. 2. Power spectrum of healthy motor under no load condition

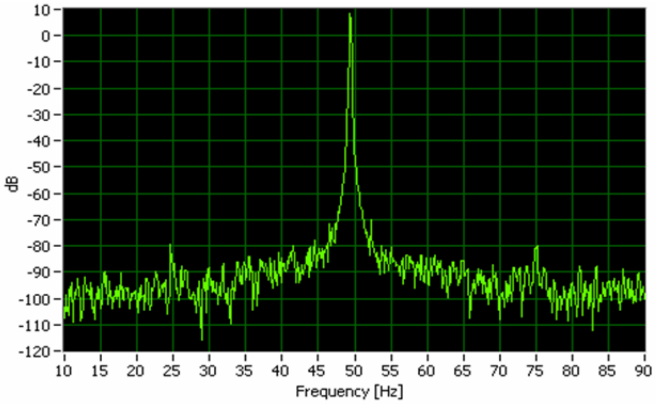

Fig. 3. Power spectrum of faulty motor with 5% shortened under no load condition

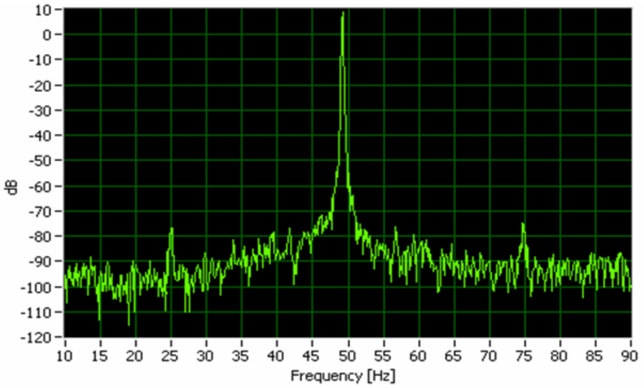

Fig. 4. Power spectrum of faulty motor with 15% shortened under no load condition

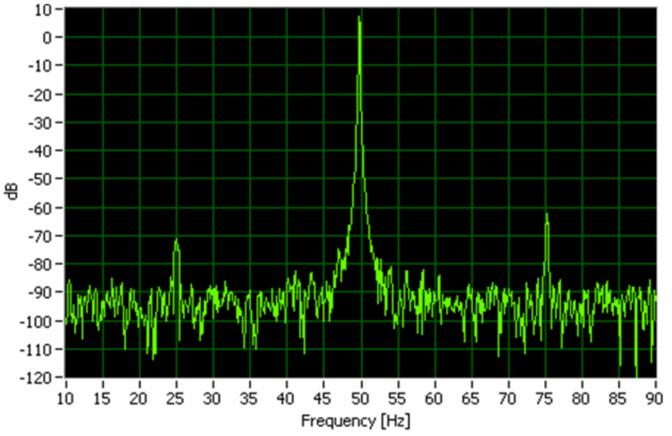

Fig. 5. Power spectrum of faulty motor with 30% shortened under no load condition

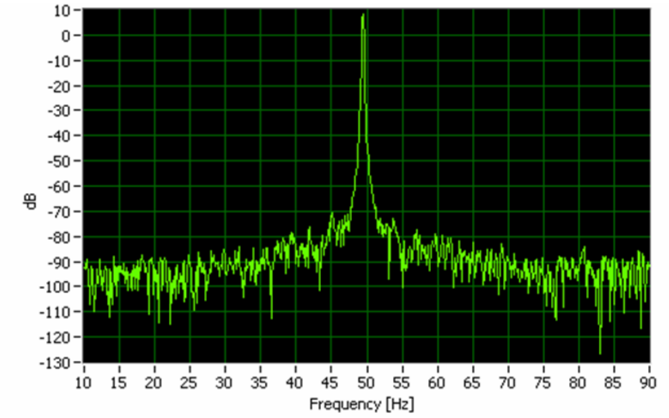

Fig. 6. Power spectrum of healthy motor under no load condition

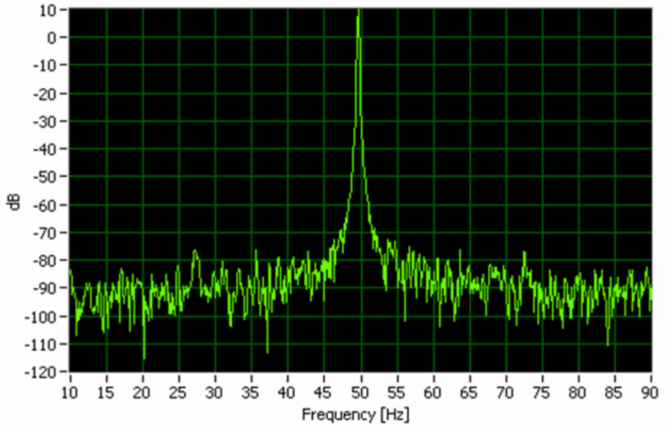

Fig. 7. Power spectrum of faulty motor with 5% shortened under full load condition

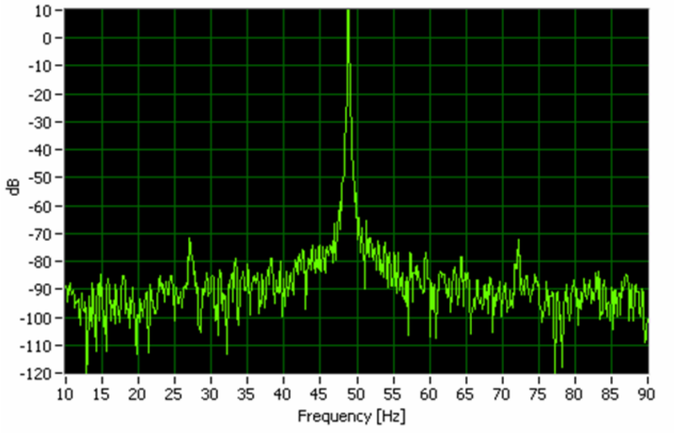

Fig. 8. Power spectrum of faulty motor with 15% shortened under full load condition

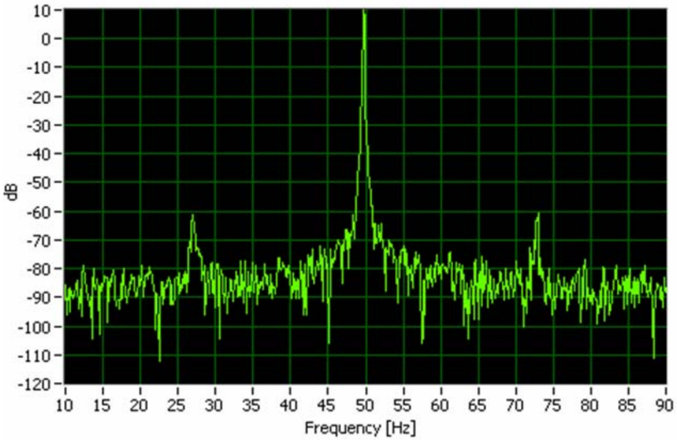

Fig. 9. Power spectrum of faulty motor with 30% shortened under full load condition

3. CONCLUSION

The stator turn fault in induction motor is studied in this paper. The type of current based by the simulation of fault are reviewed. In all condition monitoring algorithms, base measurements are taken for a healthy motor at the time of commissioning. The fault algorithm monitors the amplitude of fault frequencies and tracks changes in their amplitudes over time. A significant change in the amplitudes indicates a developing fault. Three different condition of stator turn faults are practically implemented and their effects on motor's current are studied with help of different signal conditioning techniques. The NI LabVIEW software is used to study these effects. In stator faults, harmonic shows a significant increase when fault is applied.

4. ACKNOWLEDGEMENTS

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REFERENCES

[1] Peter Vas, “parameter estimation, condition monitoring and diagnosis of electrical machines”, Clarendon Press Oxford., 1993.

[2] P. J. Tavner and J. Penman, “Condition monitoring of electrical machines”. Herfordshire, England: Research Studies Press Ltd, ISBN:0863800610, 1987.

[3] W. T. Thomson and R. J. Gilmore, “Motor current signature analysis to detect faults in induction motor derices-Fundamentals, data interpretation, and industrial case histories”, proceedings of 32nd Turbomachinery sumposium, Texas, A&M university, USA, 2003.

[4] C. M. Riley, B. K. Lin, T. G. Habetler, and G. B. Kliman, “Stator current harmonics and their causal vibrations: A preliminary investigation of sensorless vibration monitoring applications,,” IEEE Transactions on Industrial Application, Vol. 35, No. 1, pp.94-99, 1999.

[5] Benbouszid, M. E. H., “ A review of induction motors signature analysis as a medium for faults detection”, IEEE Transactions on Inductrial Electronics, Vol. 47, October, No.5, pp. 984-993, 2000.

[6] Boashash B., “Time frequency signal analysis” in: Advances in spectrum estimation and array processing, Ed. S. Haykin, Printice Hall. 1990.

[7] M. E. H. Benbouzidi, M. Viera,and C. Theys, “Induction motor faults detection and localization using stator current advanced signal processing techniques,” IEEE Transactions on Power Electronics, Vol. 14, No. 1, pp14-22, Jan. 1999

[8] Neelam Mehala, Ratna Dahiya (2009), “ A Comparative Study of FFT, STFT and Wavelet Techniques for Induction Machines Fault Diagnostic Analysis, ”, International conference on computational intelligence, Man machine systems and cybernetics, Cario, Egypt, Dec., 29-31, 2008.

[9] J. Penman, "Detection and location of interturn short circuits in the stator winding of operating motors," IEEE Transctions on Energy Conversion, Vol. 9, No.4, December 1994.