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Wavelet Analysis for Assessment of Crawling of an Induction Motor in Clarke Plane

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ABSTRACT: This paper proposes a method of wavelet decomposition based analysis for assessment of crawling of an induction motor in Clarke Plane. It has been done by assessing generated harmonics using stator current at steady state condition. Presence of different harmonics has been assessed in Clarke plane. At certain decomposition levels significant differences have been observed between those parameters found during crawling and that of normal condition. Based on the result observation and analysis an algorithm has been bee presented to assess stator current at crawling using wavelet decomposition of the current signal in Clarke plane.

Index Terms— Wavelet decomposition, Induction Motor, fault, crawling.

I. INTRODUCTION

Induction motors are widely used as electrical drives in industrial application for their robustness, low cost, good efficiency and reliability in operation. Therefore, it has become an important aspect to make the induction motors failure proof to reduce the down time of the industries. For this purpose an early detection of motor faults is highly desirable by which any catastrophic damage or any potentially dangerous situation can be avoided.

Basic concepts and techniques for detection and measurement of inter harmonics are presented in [1]. Different advanced modeling approaches have been followed in [2]-[3]. Definitions for the measurement of useful electric quantities under sinusoidal, non sinusoidal, balanced or unbalanced conditions are presented in [4]. Analysis of airgap flux, current and vibration signals as a function of the combination of static and dynamic airgap eccentricity in 3-phase Induction motors is also done [5]. Motor current signature analysis has been used for monitor and diagnosis [6] – [8]. Fault detection in induction machines has been done using power spectral density in wavelet decomposition [9]. Online diagnosis of induction motors using MCSA [10] and wavelet and PSD based Fault detection technique [11] have been introduced. Induction motor stator faults diagnosis is done by a Current Concordia [12]-[13] Pattern-Based Fuzzy Decision System. Monitoring and diagnosis of Induction motor electrical faults is done using a current Park's vector pattern approach [14]-[17]. Assessment of crawling of an induction motor is done by stator current Concordia analysis [18]. Feature pattern extraction method and Radar analysis [19] and area based approach [20] – [21] have been used in fault analysis. Clarke plane has been used in some analysis [22]-[23]. Power Quality related parameters have been monitored in Park plane [23]-[24]. Wavelet decomposition is done on stator current detection of crawling of an induction motor in Clarke plane [25].

A very common fault faced by induction motors is crawling which may occur due to the effect of generation of odd harmonics in the motor and result in lowering the speed of the motor. During crawling fifth and seventh harmonics are generated among which seventh order harmonics play vital role in lowering the speed of operation. In this paper Wavelet decomposition base Skewness and Kurtosis Analysis for Assessment of crawling of an induction motor is done in Clarke Plane.

II. CURRENT TRANSFORMATION

Currents in alpha - beta ($i_\alpha - i_\beta$) plane can be obtained from phase current multiplied by Clarke matrix as follows:

$$\begin{pmatrix} i_\alpha \\ i_\beta \end{pmatrix} = (Clarke\,Matrix) \times \begin{pmatrix} i_a \\ i_b \\ i_c \end{pmatrix} \qquad \ldots(1)$$

where, [Clarke Matrix] = (2/3) × $\begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}$

II. WAVELET ANALYSIS

Signals are transformed in Clarke plane using Clarke transformation matrix. Then wavelet (db4) decomposition is performed. The Daubechies 4 mother wavelet (Daubechies, 1992) is used here for some reasons. Several other mother wavelets (including Coifflet, Haar, and several CDFs) have been tried here, and found that Daubechies 4 most accurately found peaks when background was high or peaks were small, and with minimal distortion of the signal.

Fig. 1 – 4 shows the result of wavelet decomposition in two axes of Clarke Plane. Fig. 1 and 2 corresponds to normal condition and Fig. 3 and 4 corresponds to the signals obtained during crawling (faulty condition). To detect the faulty condition Skewness and kurtosis is used here. Skewness, can be mathematically defined as the averaged cubed deviation from the mean divided by the standard deviation cubed. If the result of the computation is greater than zero, the distribution is positively skewed. If it's less than zero, it's negatively skewed and equal to zero means it's symmetric. For Invariant data Y_1, Y_2, ..., Y_N, the formula for Skewness is:

Skewness = $\frac{\sum_{i=1}^{n}(Y_i - \bar{Y})^3}{(N-1)S^3}$ …(2)

Where $\bar{Y}$ is the mean, S is the standard deviation, and **N** is the number of data points. Kurtosis refers to the degree of peak in a distribution. More peak than normal means that a distribution also has fatter tails and that there are lesser chances of extreme outcomes compared to a normal distribution. The kurtosis formula measures the degree of peak. For data Y_1, Y_2, ..., Y_N, the formula for kurtosis is:

Kurtosis = $\frac{\sum_{i=1}^{n}(Y_i - \bar{Y})^4}{(N-1)S^4}$ …(3)

where $\bar{Y}$ is the mean, S is the standard deviation, and **N** is the number of data points. Here the two parameters Skewness and kurtosis is used to measure the condition of induction motor. Basically these parameters are used to measure the quality of power.

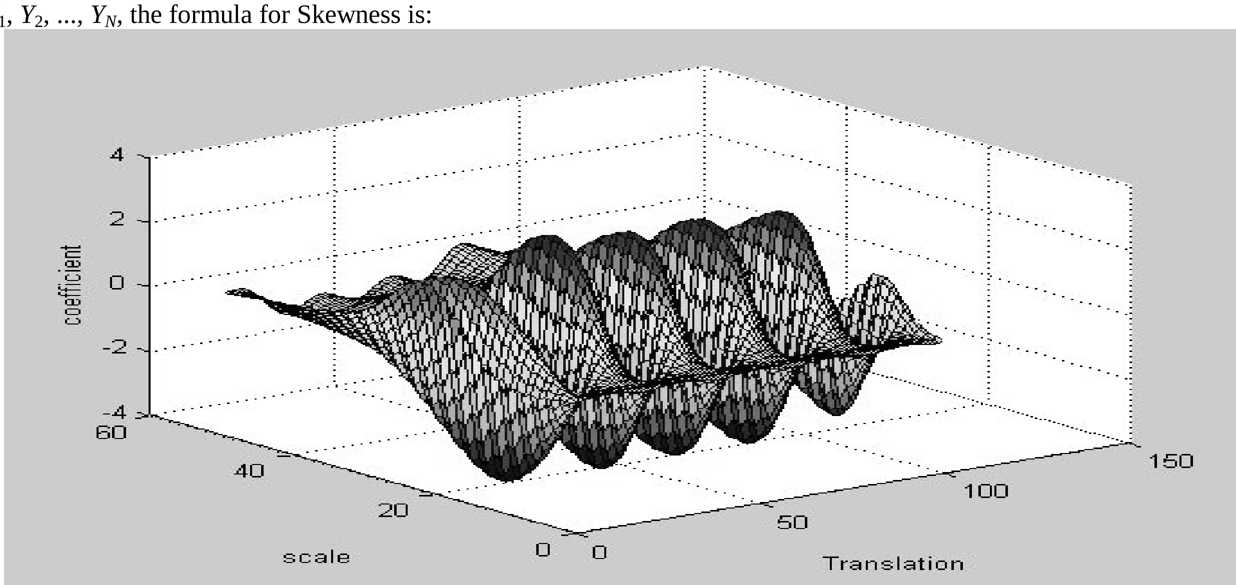

Fig. 1 i_α at normal condition.

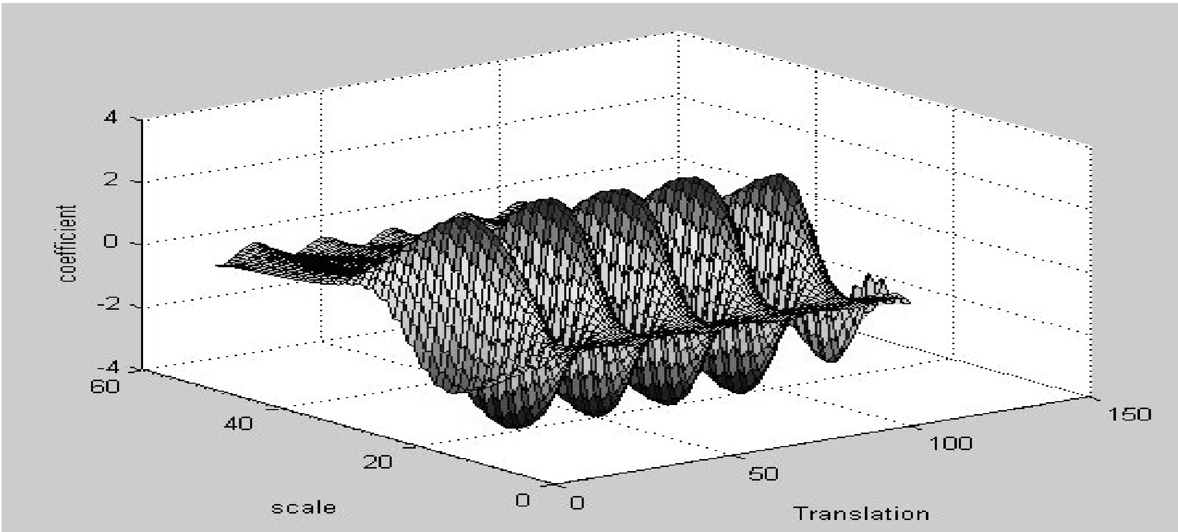

Fig. 2 i_β at normal condition.

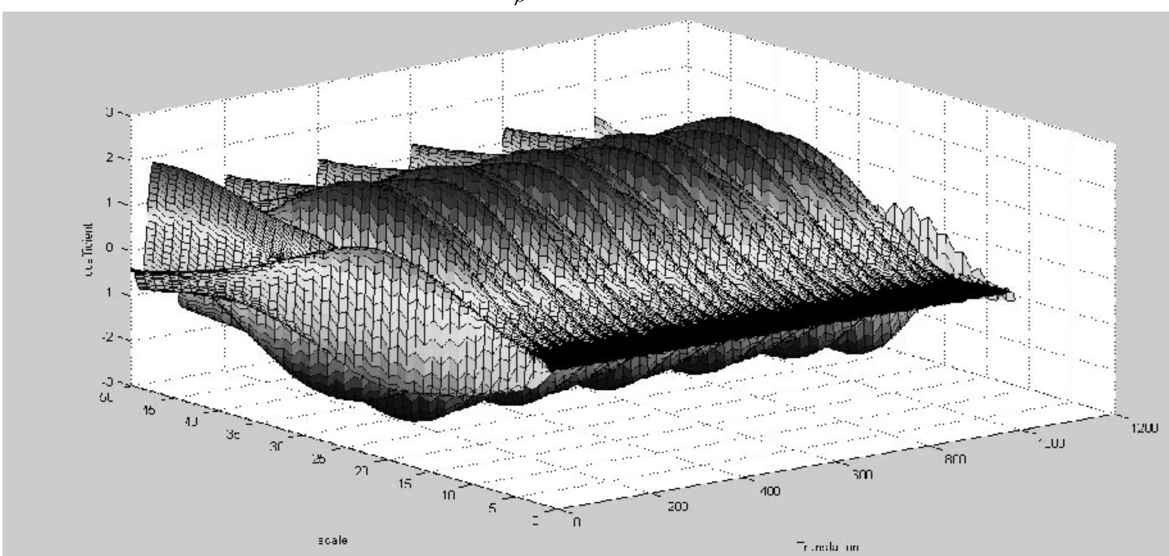

Fig. 3 i_α at crawling.

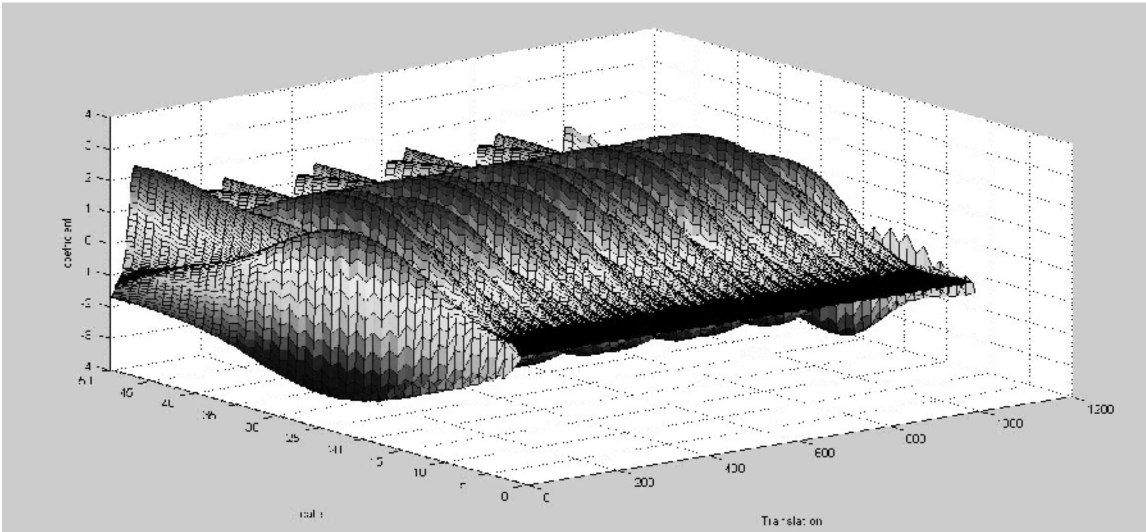

FIG. 4 i_β AT CRAWLING.

III. OBSERVATION

Figure 1 and 2 show the continuous Wavelet Transform (cwt) of i_α and i_β signal in normal condition and Figure 3 and 4 is the cwt of i_α and i_β signal in faulty condition respectively. From these figures it is clear that in faulty condition different harmonics with higher magnitudes are present in i_α and i_β signal. To cope with discrete captured, discrete-wavelet-transform (dwt) has been done using the mother wavelet as 'db4'. RMS values of approximate coefficients for i_α (alpha axis) has been plotted with respect to dwt decomposition level as shown in Fig. 5. Dashed line graph for when all harmonics are present and continuous solid line graph for only fundamental component is present. RMS values of approximate coefficients for i_β have been plotted with respect to dwt decomposition level as shown in Fig. 6. Skewness and Kurtosis of app. Coefficients are then calculated during normal and at crawling.

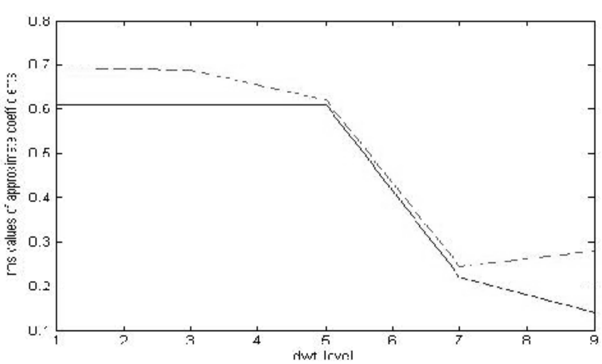

Fig. 5. RMS values of approximate coefficients for i_α at different dwt decomposition level.

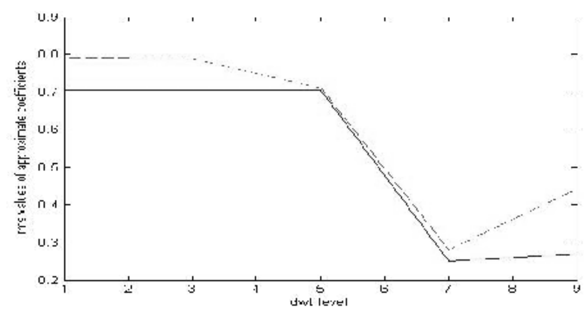

Fig. 6. RMS values of approximate coefficients for i_β at different dwt decomposition level.

From figure 5 and figure 6, it is clear that in faulty condition the magnitude of rms value is increased with respect to normal condition and after the decomposition level 7 the difference between the two plots is increased furthermore which may be the clear indication of crawling. Skewness values (in between normal and faulty condition) is found maximum in decomposition level 7. Kurtosis values are maximum up to level 3 and after that the values are decreasing. In level 5 difference is minimum and after this level again it is increasing in nature which is clear indication of faulty condition.

An algorithm for crawling or fault detection have been also made as follows:

a. Step down the stator currents through current transformer
b. Sample them
c. Capture the sampled values through data acquisition system
d. Apply discrete wavelet transform technique

e. Determine kurtosis, skewness and rms values of approximate coefficients at different dwt decomposition levels (upto 9^{th} level)

f. Compare all above values from standard or normal condition measured values

g. Diagnose the crawling conditions based on measurement and comparison of above parameters values in two conditions.

IV. Conclusion

In this paper Wavelet decomposition base Skewness and Kurtosis and RMS values of coefficients Analysis for Assessment of crawling of an induction motor in Clarke Plane has been done. It has been achieved by assessing generated harmonics using stator current at steady state condition. Presence of different harmonics has been assessed by with the help of Skewness and Kurtosis of current waveform in Clarke plane. At certain decomposition levels significant differences have been observed between those parameters found during crawling and that of normal condition which may be very useful in detection of such fault

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