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Image Processing Based Stator Fault Severity Detection and Diagnosis of Induction Motor Using Labview

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ABSTRACT

This paper deals with the fault severity detection and diagnosisof induction motor fault based on image processing using particle analysis. Index of compactness and distance between x_c coordinate of gravity center of the region and x coordinate of the mean upper point of the region (*dist_xc_tlr*) are two features extracting by image processing. Using the fuzzy logic strategy, a better understanding of heuristics underlying the motor faults detection and diagnosis process can be achieved by means of automating fault diagnosis without the intervention of anoperator.

1. INTRODUCTION

Three-phase induction motor plays a very important role in the industrial life. These motors are one of the most widely used electrical machines. To ensure a continuous and safety operation for these motors, preventive maintenance programs, with fault detection techniques, must be considered. Many condition monitoring methods have been proposed for the induction machine fault detection and classification [1].

Condition monitoring schemes have concentrated on sensingspecific failure modes. Stator faults are one of the majorelectrical machines malfunctions. These faults are linked withthe harmonics spectrum of the stator current. So, one of themost significant methods based on the analysis of the machineline currents is the motor current signature analysis (MCSA)[2]-[4]. This method is based on the motor line currentmonitoring and consequent inspection of its deviations in thefrequency domain. Another approach based on the analysis of machine line currents is the Park's vector approach [5]-[6]. This method is based on the identification of the stator current Concordia patterns. This enables the identification of the stator fault and its extension by a pattern recognition method. The Park's vector approach can be used to detect a faulty motor based on the shape of its pattern.

Under this context, this paper proposes a new method forthe detection of a three-phase induction motor stator fault. Thismethod is based on the image identification of the statorcurrent Concordia patterns. The index of compactness (*I.O.C.*)and distance between the x_c coordinate of the Gravity centerof the region and the x coordinate of the mean upper point ofthe region (*dist_xc_tlr*) are based on visual features. This will allow the identification of turn faults in the stator winding and its correspondent severity. The identification ofthe faulty phase is another important feature of the proposed method.

2. PARK'S VECTOR APPROACH

The analysis of the three-phase induction motor can be simplified using Clark-Concordia transformation. This transformation allows the reduction of a three-phase system into a two-phase equivalent system. In three phase induction motor the connection to the mains usually does not considers the neutral. Under this situation the three phase induction motor αβ line currents are given by:

$$i_\alpha = \sqrt{\frac{2}{3}}i_a - \sqrt{\frac{1}{6}}i_b - \sqrt{\frac{1}{6}}i_c$$

$$i_\beta = \sqrt{\frac{1}{2}}i_b - \sqrt{\frac{1}{2}}i_c$$

A healthy three-phase induction motor generates a circular pattern, assuming an elliptic pattern whose major axis orientation is associated to the faulty phase. This elliptic pattern also changes according to the fault severity. For more severe faults the eccentricity of the ellipse increases. This is shown using *Labview* graphical coding presented as Fig.1 and Fig.2

3. IMAGE PROCESSING BASED SYSTEM

A feature-based recognition of stator pattern current independent of their shape, size and orientation is the goal of the proposed method. Finding efficient invariants features are the key to solve this problem. Particular attention is paid to visual-based features obtained in the image processing system.The proposed image processing is divided in three stages: image composition, particle analysis and feature extraction as shown in Fig.3. The inputs for the image processing based system are the αβ currents and the outputs are *I.O.C* and *dist_xc_tlr* feature values.

3.1. IMAGE COMPOSITION

In the image composition stage, the αβ stator currents are first represented as an image in order to be used in the pattern recognition method. Each pixel belonging to the object contour represents each αβ sample current.

A binary image can be considered as a particular case of a grey image with *I(x,y)=1* for pixels that belongs to an object, and *I(x,y)=0* for pixels that belongs to the background. Fig.4 shows the αβ stator currents represented in the image plain after image composition process.

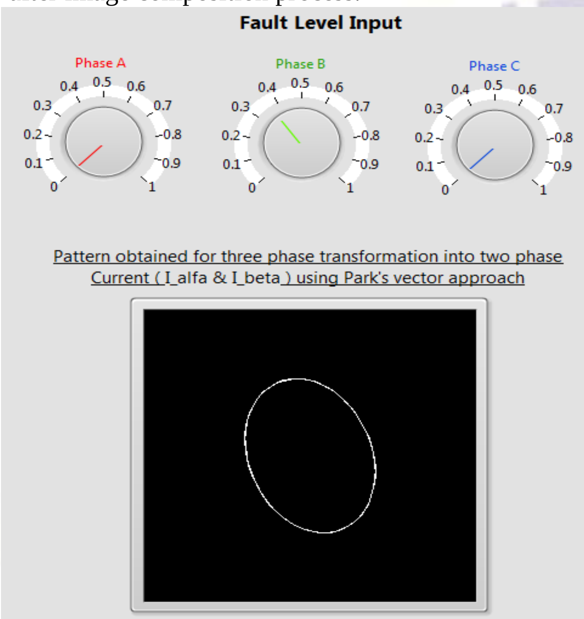

Figure1. Front Panel displaying fault pattern

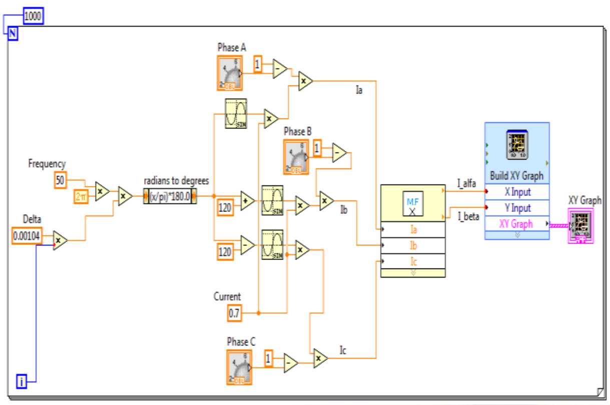

Figure2. Graphical code for pattern generation

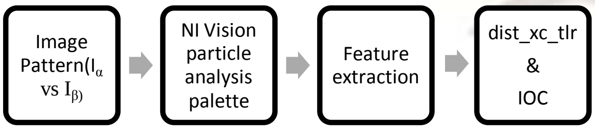

Figure3. Structure of image processing based system

3.2. PARTICLE ANALYSIS

In the pattern recognition method, after image composition it is necessary to determine the shape of the region. To represent the boundary of the region and at the same time obtain some properties that help feature extraction the NI vision particle analysis palette is used [7]. This method leads to anefficient calculation of the region area and its contour perimeter.

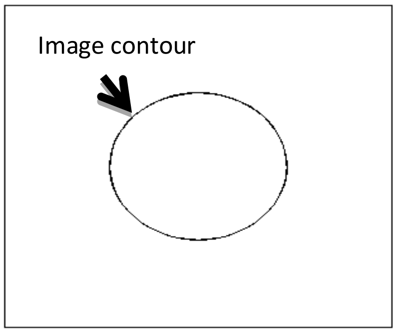

Figure4. Image plan for the αβ line currents

During the contour following right and left upper points(*tr_p, tl_p*) of the region were obtained using particle measurement of first pixel through which the last pixel on the first line of the region.

3.3. FEATURE EXTRACTION

The feature extraction stage uses the area of the object and the contour perimeter to compute the index of compactness. To obtain the distance between the x_c coordinate of the gravity center of the region and the *x* coordinate of the mean upper point of the region it is necessary to compute the gravity center (x_c, y_c)[8].

The index of compactness and the distance between the $x_c$coordinate of the gravity center of the region and the x coordinate of the mean upper point of the region are the key features for the fault diagnosis procedure.

Assume that the pixels in the digital image are piecewise constant and the dimension of the bounded region image for each object is denoted by M×N pixels, the visual features, area and perimeter, used to determine the I.O.C. can be obtained as [9]:

$$A(I) = \sum_{x=1}^{M} \sum_{y=1}^{N} I(x,y)$$

$$P(I) = \sum_{x,y} Arc_{xy}$$

Where Arc_{xy} is the length of the arc along the object contour, where x and y are neighbors.

The index of compactness is then given by:

$$IOC(I) = \frac{A(I)}{P(I)^2}$$

Physically, the index of compactness denotes the fraction of maximum area that can be encircled by the perimeter actually occupied by the object.

The coordinate x_c of the gravity center is given by:

$$x_c = \frac{\sum_{x=1}^{M} \sum_{y=1}^{N} I(x,y).x}{A(I)}$$

The distance between the x_c coordinate of the gravity center of the region and the x coordinate of the mean upper point of the region is given by:

$$dist\_x_c\_tlr(I) = x_c - \left(\frac{tl\_p + tr\_p}{2}\right)$$

Where tl_p and tr_p are the x coordinates of the top-left and the top-right points of the region.
In fig.5 it is shown that distance between the x_c coordinates of the gravity center of the region and the x coordinates of the mean point between the top-left and top-right points of the regionevaluation code.

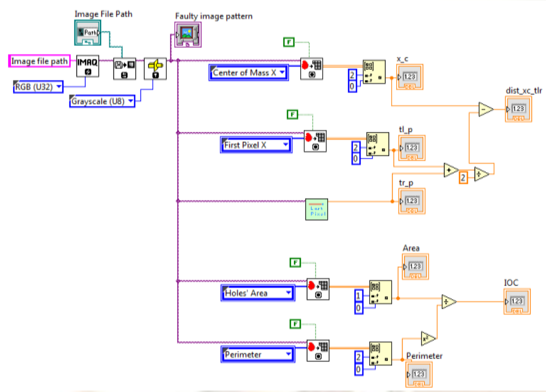

Figure 5. Graphical code for feature extraction

4. INDUCTION MOTOR FAULT DETECTION AND INDICATION

A block diagram of the induction motor detection and simulation results of fault type with *I.O.C* and *dist_xc_tlr* are presented in fig.6 and table.1 respectively.

SIMULATION RESULTS

The system shown in fig.6 was simulated in the *Labview* environment. The induction motor was initially simulated without fault. In this case the corresponding αβ vector pattern is a circle.
Table.1 presents the obtained results for the two features. When the induction motor has no fault the index of compactness is, approximately, 0.0822694. Fig.7 presents the current vector pattern for the healthy motor, which does not present any eccentricity. For a small induction motor fault, the index of compactness decreases to 0.0224325, denoting that the αβ pattern exhibits some eccentricity.

As can be seen by the results presented in Table.1 the distance between the $x_c$coordinate of the region gravity center and the mean pointbetween the top-left and top-right points of the region(*dist_xc_tlr*), is different for each phase fault, denoting thisdistance value the faulty phase. As the fault becomesmore severe, the *I.O.C* decreases and the *dist_xc_tlr* increaseits absolute value.Figure 7, 8 and 9 shows the simulation results of current pattern for healthy motor, motor with severe fault, and motor with small fault respectively.

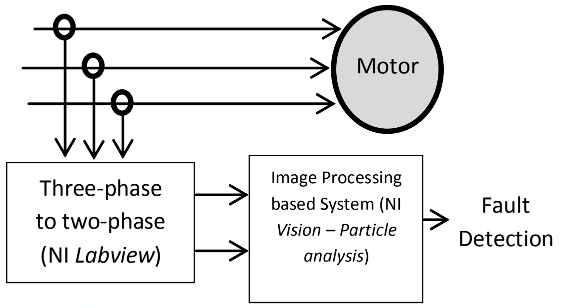

Figure6.Structure of proposed fault detection system

TABLE.1. Simulation results

Fault type	*I.O.C*	*Dist_xc_tlr*
No fault	0.0822694	-0.529
Phase A reduced fault	0.0224325	-0.506
Phase A higher fault	0.0812921	-0.508
Phase B reduced fault	0.0750095	24.4
Phase B higher fault	0.0584286	59.4
Phase C reduced fault	0.0751506	-25
Phase C higher fault	0.0581938	-60.5

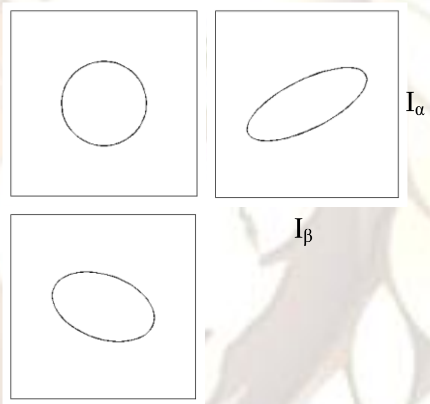

Fig: 78 9

αβvector pattern for different severities of faults

A multi-input single output (MISO) fuzzy controller is fed with a fuzzy rule based system. Inputs are *IOC* and *dist_xc_tlr*that are obtained from processed image and output is fuzzy output value. This output is given to a fault severity detection and indication system which shows severity of fault as a color variation. If the severity of fault is low then it shows orange color indication, red for high severity of fault and green for no fault case. Fig.10 and fig.11 shows the graphical user interface with fault severitydetector and indicators and graphical code for fault phase detection and color indication respectively.

Fault indication system is given with fuzzy output value with IOC and dist_xc_tlr values obtained from image processing system as input to fuzzy system results in auto fault phase detection and fault severity indication. Fig.12 shows entire process of detection and indication as a simple block diagram representation.

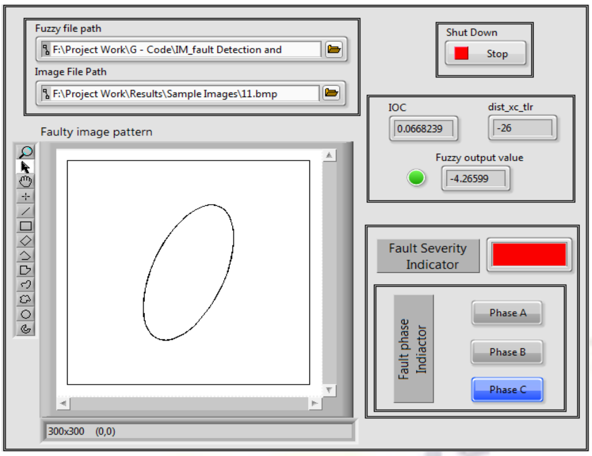

Figure10. Fault phase and severity indicator

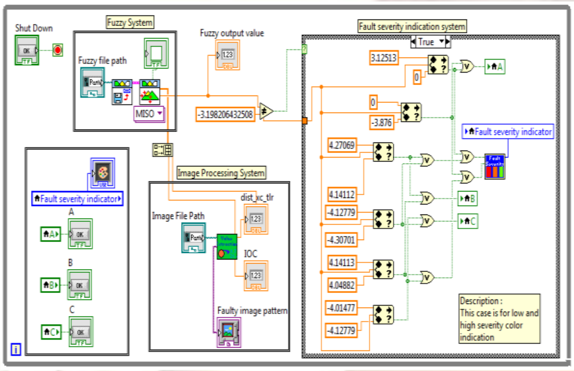

Figure11. Graphical code for fault phase detection and severity indication

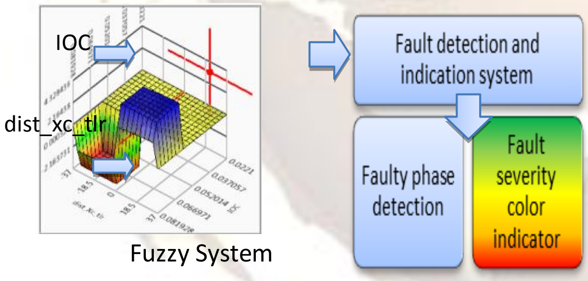

Figure12. Fault detectionthrough fuzzy rule based system

5. CONCLUSION

In this paper, based on the αβ line current vector image pattern, for the identification of a three-phase induction motor stator phase fault was presented. In the system recognition, feature extraction based on index of compactness and the distance between the x_c coordinate of the pattern gravity center and the mean point between the top-left and top-right points were done by particle analysis that fed to fuzzy system,detects the faulty phase and indicates the severity of fault automatically.

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