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Fault Diagnosis Using Park's Vector Approach

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Abstract

This paper has proposed a methodology by which induction motors electrical faults can be diagnosed by monitoring the stator current by computer. The proposed methodology was based on the so-called Park's vector approach. In fact, stator current Park's vector patterns used to discern between 'healthy' and 'faulty' induction motor. The results obtained from the experiment show that current park's vector pattern of healthy motor was perfect circle while current park's vector pattern under faulty condition was elliptical in shape. In this way, the short winding fault of induction motor can be easily diagnosed by comparing the Park's vector representations. Thus, the laboratory experiment proves the effectiveness of this technique in area of computer aided condition monitoring of induction machines.

Introduction

Induction machines are horse power of industries for many years. These machines have been used in all kinds of electric drives more often than any other electric motor. An induction machine is defined as an asynchronous machine that comprises a magnetic circuit which interlinks with two electric circuits, rotating with respect to each other and in which power is transferred from one circuit to the other by electromagnetic induction. It is believed that a large portion of stator winding-related failures are initiated by insulation failures in several turns 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 circulating current to flow and subsequently generates excessive heat in the shorted turns. 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 fifty precent for every ten degree increase above the stator winding temperature limit. It is thus necessary to monitor the stator winding temperature so that an electrical machine will not operate beyond its thermal capacity. For this purpose, many techniques have been reported. However, the inherent limitation of these techniques 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 air-gap 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.

Fault Diagnosis Using Park's Vector

In three phase induction motors, the connection to the mains does not usually use the neutral. Therefore, the main current has no homopolar component. A two dimensional representation can then be used for describing three phase induction motor phenomena, a suitable one being based on the current Park's vector [15].

As a function of mains phase variable (i_a, i_b, i_c) the current Park's vector components (i_d, i_q) are [16-22]:

$$i_d = \sqrt{\frac{2}{3}} i_a - \frac{1}{\sqrt{6}} i_b - \frac{1}{\sqrt{6}} i_c \tag{1}$$

$$i_q = \frac{1}{\sqrt{2}} i_b - \frac{1}{\sqrt{2}} i_c \tag{2}$$

Under ideal conditions, three phase currents lead to a Park's vector with the following components:

$$i_d = \frac{\sqrt{6}}{2} I \sin \omega t \tag{3}$$

$$i_q = \frac{\sqrt{6}}{2} I \sin\left(\omega t - \frac{\pi}{2}\right) \tag{4}$$

where

I= maximum value of the supply phase current

ω_s =supply frequency

t =time variable

Its representation is a circular pattern centered at the origin of the coordinators. This is very simple reference figure that allows the detection of abnormal conditions by monitoring the deviations of acquired patterns.

Short winding fault is also diagnosed with Park's vector approach. The analysis of the three-phase induction motor can be simplified using the Park transformation. The method is based on the visualization of the motor current Park's vector representation. If this is a perfect 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 can be established. The ellipticity increases with the severity of the fault.

Data Acquisition

In order to diagnose the fault of induction motor with high accuracy, a modern laboratory test bench was set up. It consists of three phase induction motor coupled with rope brake dynamometer, transformer, NI data acquisition card PCI-6251, data acquisition board ELVIS and Pentium-IV Personnel Computer with software *LabVIEW 8.2.* The rated data of the tested three-phase squirrel cage induction machine were: 0.5 hp, 415V, 1.05 A and 1380(FL) r/min.

In the experiment, the speed of the motor is measured by digital tachometer. The virtual instrument (VIs) was built up with programming in LabVIEW 8.2. The VIs was used both for controlling the test measurements and data acquisition, and for the data processing. In order to test the system in practical cases, several measurements were made to read the stator current of a motor.

Experimental Results

To get the Park's vector pattern, the programming is done with signal processing module of LabVIEW software. The induction motor has been initially tested, in the absence of faults in order to determine the reference current Park's vector pattern corresponding to the supposed healthy motor. Afterward, short circuited motor was tested.

Figure 1 shows a Current Park's vector pattern for healthy motor which is a perfect circle where instantaneous magnitude is constant. An unbalance due to short winding faults results in different representation of the park's vector is shown in Figure 2. It could be seen that current pattern for faulty motor is clearly different from current pattern of the healthy motor.

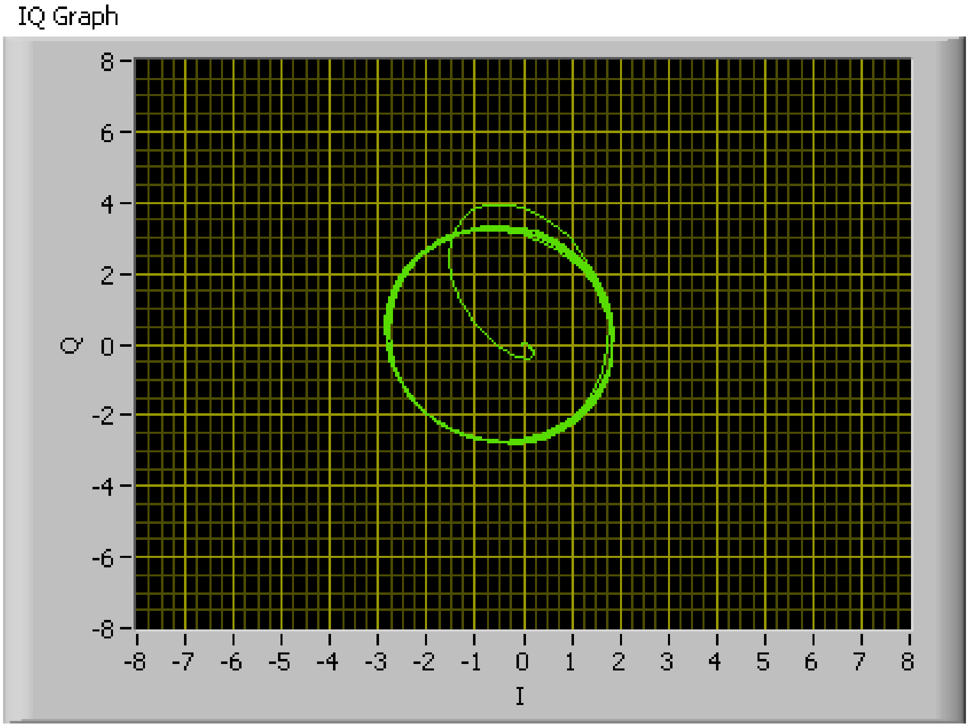

Figure 1: Current Park's vector pattern for healthy motor

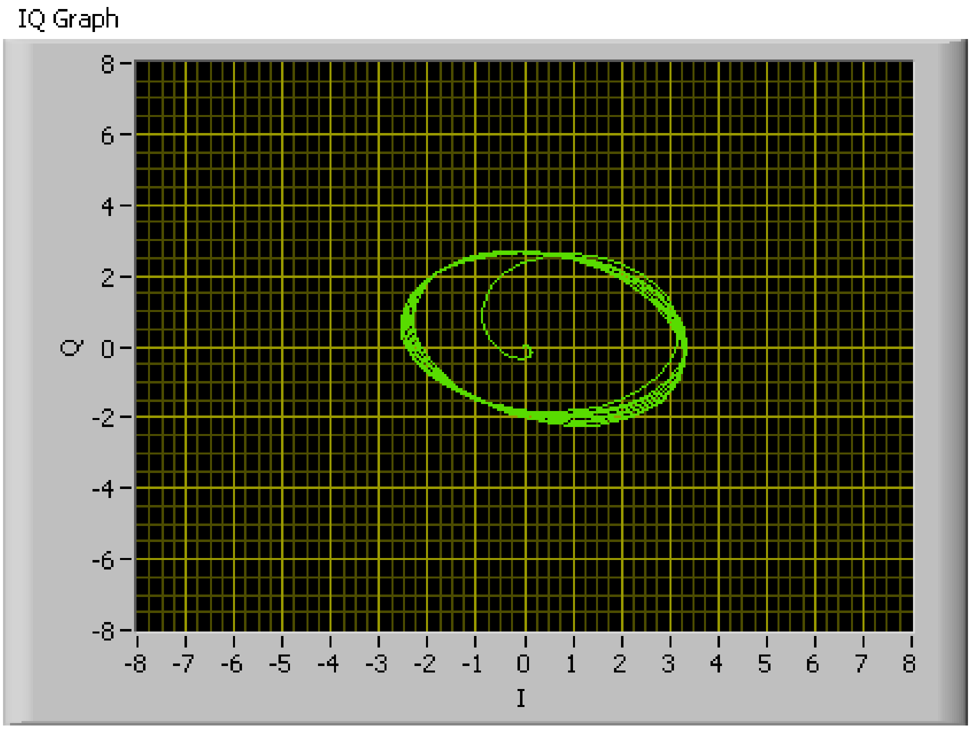

Figure 2: Current Park's Vector pattern for short circuited motor

The shape of the current's phasor in Figure 2 is not of perfect circular shape. The elliptical shape of current's phasor indicates short winding fault in the squirrel cage induction machine. Thus, by comparing the current pattern of healthy and faulty motor, the short winding fault can be easily diagnosed.

Conclusion

On-line detection of short winding fault in three-phase induction motors is discussed in this paper. The park's vector representation is obtained using Virtual instrument. The Virtual Instrument is obtained by programming in software. It is observed from the experiments that current park's vector pattern of healthy motor was perfect circle while current park's vector pattern under faulty condition was elliptical in shape. Experimental results, obtained by using a special fault producing test rig, demonstrate the effectiveness of the proposed technique, for detecting the presence of short winding fault in operating three-phase induction machines. Thus, short winding fault can be identified with help of park's vector approach.

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