

## ***Fault Diagnosis of 3- $\Phi$ Induction Motor Using Park's Vector Approach***

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### ***Abstract***

*This paper proposes a method by which Electrical Faults of 3- $\Phi$  Induction Motors can be diagnosed by a Computer Monitoring the Stator Current. A Computer Monitoring Diagnosis based on the proposed methodology was based on the so-called Park's vector approach. The stator current park's vector pattern has been discerning between 'Healthy' and 'Faulty' 3- $\Phi$  Induction Motors. The results obtained from the experiment show that current Park's vector pattern of the healthy motor was a perfect circle. In contrast, current Park's vector pattern under faulty condition was elliptical. In this way, the short winding fault of the 3- $\Phi$  induction motor can be easily diagnosed by comparing Park's vector representation. This laboratory experiment proves the effectiveness of the park vector in monitoring induction machines with the help of computers.*

***Keywords: - Park's Vector Approach, Electrical Faults, Faulty condition***

### **INTRODUCTION**

Induction machines are horsepower 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 an

asynchronous machine that comprises a magnetic circuit that interlinks with two electric circuits, rotating with respect to each other. Power is transferred from one circuit to the other by electromagnetic induction. It is believed that insulation

failures initiate a large portion of stator winding-related failures in several turns of a stator coil within one phase. This type of fault is referred to 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 that is proportional to the circulating current's square exceeds the limiting value, 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: ageing, overloading, and cycling. Even the best insulation may fail quickly if the motor is operated above its temperature limit. As a rule of thumb, fifty per cent of the life of insulation is reduced for every ten-degree increase above the stator winding temperature limit. Thus, it is

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, these techniques' inherent limitation 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, air gap eccentricity, and broken rotor bars. The current in the stator winding produces a force on the coils proportional to the square of the current. This force is at its maximum under transient overloads, causing the coils to vibrate 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 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

This approach requires current sensing, not on one but all three phases, Figure 1. Park's current vector can be computed from the symmetrical three-phase current system, having the components:  $i_a$ ,  $i_b$ , and  $i_c$  giving Park's vector

components  $i_d$  and  $i_q$ , as described in (3) and (4). Figure 2 depicts Park's transformation concept with quadrature and direct axes in the induction machine. The figure illustrates the conventional three axes, a, b and c, transformed to a new reference frame with two axes, direct and quadrature.

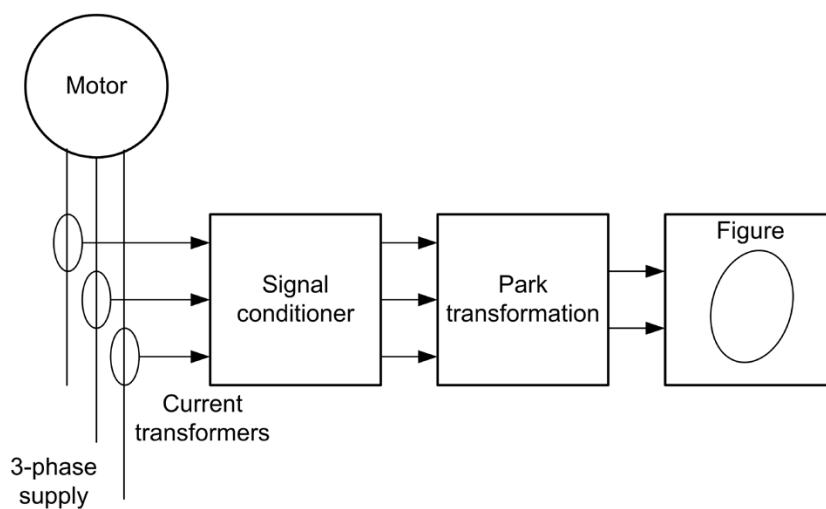


Figure 1: Block Diagram of MCSA Using Park's Vector Approach

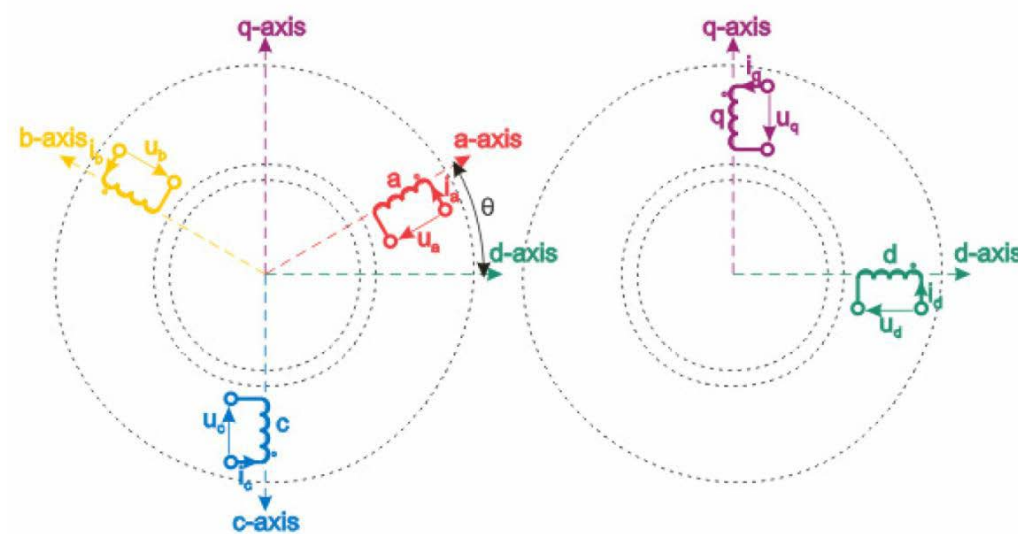


Figure 2: Park's Transformation

The induction machine if healthy its three-phased stator current system is perfectly symmetric:

$$\begin{aligned} i_a &= \sqrt{2}I \sin(\omega_s t) \\ i_b &= \sqrt{2}I \sin\left(\omega_s t + \frac{2\pi}{3}\right) \\ i_c &= \sqrt{2}I \sin\left(\omega_s t + \frac{4\pi}{3}\right) \end{aligned} \quad (1)$$

The transformation of the three-phased system to the two-phased orthogonal one can be performed upon

$$\begin{bmatrix} f_d \\ f_q \\ f_0 \end{bmatrix} = [P_{dq0}] \begin{bmatrix} f_a \\ f_b \\ f_c \end{bmatrix} \quad (2)$$

Where  $f$  is the function to be transformed (it can be the current, voltage or magnetic flux).

The Park transformation matrix is:

$$|P_{dq0}| = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos(\theta) & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta - \frac{4\pi}{3}\right) \\ -\sin(\theta) & -\sin\left(\theta - \frac{2\pi}{3}\right) & -\sin\left(\theta - \frac{4\pi}{3}\right) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \quad (3)$$

By using the above transformation the orthogonal components of the Park's current vector can be computed from the symmetrical three-phased current system, having the components:  $i_a$ ,  $i_b$  and  $i_c$ :

$$i_d = \sqrt{\frac{2}{3}} \left[ i_a \cos \theta + i_b \cos \left( \theta - \frac{2\pi}{3} \right) + i_c \cos \left( \theta + \frac{2\pi}{3} \right) \right] \quad (4)$$

$$i_q = -\sqrt{\frac{2}{3}} \left[ i_a \sin \theta + i_b \sin \left( \theta - \frac{2\pi}{3} \right) + i_c \sin \left( \theta + \frac{2\pi}{3} \right) \right]$$

If the reference is fixed in the stator of the machine ( $\theta = 0$ ) the above equation becomes:

$$i_d = i_a - \frac{i_b}{2} - \frac{i_c}{2} \quad (5)$$

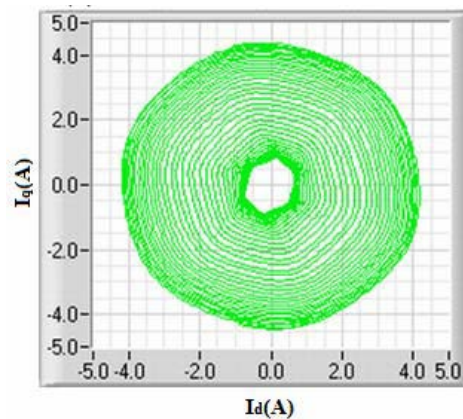
$$i_q = \frac{\sqrt{3}}{2} (i_b - i_c)$$

In this case by replacing (5) in (4) the following equation can be obtained for the two orthogonal components of Park's current vector in the case of a healthy electrical machine:

$$i_d = \frac{3}{2} I_M \sin(\omega t) \quad (6)$$

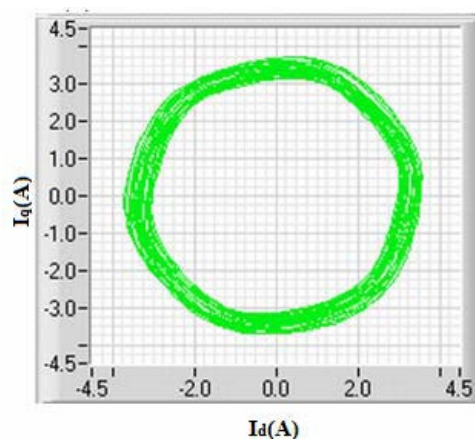
$$i_q = \frac{3}{2} I_M \cos(\omega t)$$

Upon equation (6) it can be stated that that a healthy machine shows a perfect circle in Park's vector representation, as shown in Fig. 3.



**Figure 3: The plot of Park's current vector for a healthy machine during startup**

When any type of fault occurs the three-phased current phase current system becomes unbalanced. This result in an elliptic representation of the Park's current vector (see Fig. 4).



**Figure 4: the Plot of Park's Current Vector for a Faulty Machine in Steady-State Regime**

Park's vector-based approach is widely used in the diagnosis of the most common faults of induction machines. From the parameters of the ellipse, the fault's gravity can be established. If the severity of the fault increases, the representation's elliptical form will be more highlighted [13].

If this method is used alone, it encounters difficulties in isolating the squirrel cage induction machine faults because different faults may cause a similar deviation in the Park's vector. Unfortunately, it cannot distinguish the effects of the non-symmetries of the feeding voltage or of the machine itself not connected to the faults.

## CONCLUSION

The presented methods are non-invasive fault detection techniques. Compared with Fourier transform-based methods, the two ways in a discussion can detect faults even in electrical machines with light or variable load. Detailed methods allow continuous real-time tracking of various types of faults in squirrel cage induction motors operating under continuous stationery and non-stationary conditions. These recognize the electrical machine's fault signatures and estimate the faults' severity under different load conditions.

## REFERENCES

- I. IAS MR Working Group, "Report of large motor reliability survey of industrial and commercial installation, IEEE Trans. Industry Applications, vol. I-A-21, pp. 853-864, Jul/Aug, 1985.
- II. J. Sottile et al, "An on-line method to detect incipient failure of turns insulation in random-wound motors," IEEE Transaction on Energy Conversion, vol. 8, no 4, pp. 762-768, Dec, 1993.
- III. S.B.Lee, R. M. Tallam, and T. G. Habetler, "A robust, on-line turn-fault detection technique for induction machines based on monitoring the sequence component impedance matrix," IEEE Transactions Power Electronics, vol. 18, no.3, pp. 865-872, May, 2003.
- IV. A. H. Bonnet and G. C. Soukup, "Cause and analysis of stator and rotor failures in three- phase squirrel case induction motors," IEEE Trans. Industry Application, vol., 28, no., 4, pp.921-937, Jul/Aug, 1992.

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- V. T. A.Lipo, “ Introduction of AC machine design”, Wisconsin Power Electronics Research Center, 2nd edition, 2004.
- VI. S. F. Farag, R. G. Bartheld, and W. E. May, “Electronically enhanced low voltage motor protection and control,” IEEE Trans. Industry Applications, vol. 29, no.1, pp. 45-51, Jan/Feb, 1994.
- VII. J. T. Boys and M. J. Miles, “Empirical thermal model for inverter-driven cage induction machines,” IEE Proc., Electr. Power Application, Vol. 141, pp. 360-372,1994.
- VIII. S.B.Lee and T.G.Habetler, “An online stator winding resistance estimation technique for temperature monitoring of line-connected induction machines,” IEEE Trans. Industry Applications, vol. 39, no.3, pp. 685-694, May/Jun, 2003.
- IX. W.L.Roux et al “Detecting rotor faults in permanent magnet synchronous machines,” in Conf. Rec. SDEMPED’03, pp. 198-203, Atlanta, GA, USA, August, 2003.
- X. J.R.Stack, T. G. Habetler, and R. G. Harley, “Bearing fault detection via autoregressive stator current modeling,” IEEE Trans. Industry Applications, vol. 40, no.3, pp. 740-747, May/Jun, 2004.
- XI. M.A.Cash, “Detection of turn faults arising from insulation failure in the stator windings of AC machines,” Doctoral Dissertation, Dept. of Electrical and Computer Engineering, Georgia Institute of Technology, USA, 1998.
- XII. D.E.Schump, “Predict motor failure with insulation testing,” Pulp and Paper Industry Tech Conference 1997, pp.48-50, Cincinnati, OH, USA, Jun, 1997.
- XIII. D.E.Schump, “Reliability testing of electric motors,” IEEE Trans Industry Applications, vol. 25, no. 3, pp. 386-390, May/Jun, 1989.
- XIV. R. Maier, “Protection of squirrel-cage induction motor utilizing instantaneous power and phase information,” IEEE Trans. Industry Applications, vol. 28, pp. 376-380, Mar/Apr, 1992.
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- XV. A.J.M. Cardoso et al., “Computer aided detection of air gap eccentricity in operating 3-phase induction motors by Park’s vector approach” IEEE Transactions. On Industrial Applications, vol.29, pp. 897–901, Sep/Oct 1993.
- XVI. F. Y. Lee, A. Navid, and L. Pilon, “Pyroelectric waste heat energy harvesting using heat conduction,” Appl. Thermal Eng., vol. 37, pp. 30–37, Dec. 2011.