Fault Diagnosis in a Three-phase Induction Motor Using Enhanced Park Vector Approach

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Abstract*— As a need to reduce cost and minimize losses associated with downtime, early fault diagnosis has become necessary for more reliable, efficient, and productive industrial maintenance practices. This research was able to optimize the Enhanced Park Vector Approach (EPVA) by maximizing the advantage of the visualized Park vector plot, whose distortion is directly proportional to the degree of faults, to diagnose and compute the Fault Severity Index (FSI) of an occurred fault. The research was simulated on MATLAB using the mathematical model of an induction motor (IM). Iterative values of 0%, 1%, 3%, 5%, and 10% of inter-turn short circuit (ITSC) fault were used to study the state of the IM. The research was able to contribute to an effective mathematical computational method of computing the severity of fault using standard deviation and variance.

Keywords—EPVA, Park Vector Modulus, Fault Severity Index, Park Vector Plot, Standard Deviation, Variance

I. Introduction

In recent years, diagnostic operations have become incorporated into the operational systems of IM. Some IM parameters have been employed to develop several techniques for faults diagnosis. Some of these parameters as reportedly used include currents and voltage signals [1, 2], stray flux [3], instantaneous power factor [4] and so on. Machine learning techniques were reportedly used by [5, 6] to automate diagnostic processes. Some of the techniques developed have been found to express strength in some kinds of faults and high unreliable results in others. Also, the operating conditions (whether steady or transient state) of the machine have been found to have significant effects on the techniques used [6]. However, [7] in their experiment on thirteen widely known and used techniques, reported that the EPVA is the second-best reliable technique in diagnosing faults and the best for diagnosing faults of low magnitudes. The EPVA is more suitable to differentiate emerging faults from transient load oscillation conditions that may occur in the machine due to high starting torque [8]. These have given greater credit to the EPVA in IM condition monitoring since most IM faults (especially ITSC faults) start as incipient faults of low magnitude [9].

The EPVA technique is fundamentally based on the Park Vector Approach (PVA) but with an advanced spectral analysis using soft signal processing to analyse the Park Vector Modulus (PVM). With the PVM analysis, the result from the PVA is more efficient and reliable [10]. EPVA utilises the IM current parameters to diagnose various kinds of faults in the IM. As a result, it is an online diagnostic technique that has insignificant interference with machine operations [11].

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In this research, the EPVA technique was used to diagnose ITSC faults in an IM based on a MATLAB simulation-based modelling and further computations were carried out to check for the fault severity in the IM. This research paper is structured as follows. Section II–III present the mathematical modelling of the three-phase IM in the *ABC* coordinate system and direct-quadrature (dq) reference frame system respectively. Section IV presents the proposed methodology adopted in this research. Section V shows the simulation results obtained and the discussions of those results. Finally, in section VI, the conclusions were drawn from the research.

II. Modelling of ITSC Fault of an IM in ABC Coordinate System

For this research, it is assumed that:

- The three-phase system is a balance system.
- The induction motor has symmetrical and identical distributed windings.
- The ideal state of the motor is considered, that is, the effect of saturation, eddy current, friction and winding losses are neglected.
- The motor has a uniform air gap between the stator and the rotor cores.
- The three-phase IM is considered to have a delta configuration on its windings [12, 13].

Asymmetrical three-phase IM with ITSC fault on the a-phase is shown in Fig. 1.
Where,

N_{asu}, numbers of shorted A-phase stator windings,

N_{ash}, numbers of healthy A-phase stator windings,

i_f, the circulating fault current flowing in the shorted resistive path.

Using Kirchhoff Current Law (KCL), the current flowing in the shorted turns is $i_{as} - i_f$.

In a balanced system, the number of windings and resistances on the stator and rotor are respectively equal.

The total number of turns, N_s on the stator a-phase winding is expressed in terms of shorted and healthy turns as:

$$N_s = N_{ash} + N_{asu} \quad (1)$$

Similarly,

$$R_s = R_{ash} + R_{asu} \quad (2)$$