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Internal Fault Detection of Induction Motor using Frequency Response Analysis Technique

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ABSTRACT

Stator winding breakdown largely contributes to induction motor failures. To understand internal fault in induction motor winding. This paper presents a method for detection and diagnosis of three-phase induction motor electrical failures. The presented method uses Frequency Response Analysis (FRA) technique for detection of both short-circuit (SC) fault and phase-to-phase (PP) fault in induction motor. In this paper, the FRA response interpretation on internal SC fault and PP fault at two different units of three-phase induction motors. Each unit presented in two conditions: at healthy winding condition and at windings shorted condition. The method developed in this study can be used for diagnosis and detection the other types of faults in machines windings.The applications of developed method can be used for detection the faults of other machines types.

Key words: Stator winding fault, Short circuit fault, Phase to phase fault, Frequency response analysis.

1. INTRODUCTION

Three-phase induction motors (TPIM) are irreplaceable components in industrial plants. TPIM are also commonly used in manufacturing of commercially available equipment. In which almost 95% of the motors used in industries are TPIM due to its features compared to other types of rotating machines [1], [2], [3]. The major reasons behind using of TPIM applications are performance, efficiency, reliability and safety. Monitoring the health of induction motor is very critical because of the machine cost and remaining life may cause it easy to breakdown. Induction motors failure mechanism are different and depended on many parts and various factors such as material used, operating condition and environmental conditions. The most important part in a TPIM is probably the stator winding [4].

The stator and rotor faults which usually happen in TPIM are categorized as electrical faults [5]. According to several studies, (36%) of motor failures are because of stator winding faults [6], [7]. Failure in stator winding's insulation is considered as the most common reason of TPIM failure [5]. The percentage of failure cases reported due to this category was range between 30% and 40% [8]. Occasionally, the losses in production, high maintenance cost and major faults happened because TPIM windings failure. Therefore, to avoid any catastrophic failure in which it may cause unwanted downtime of production or even replacing the TPIM and pay money for that, it is better for faults to be detected and diagnosis in incipient level [9].

This paper present the effect of faults occurs in induction motor windings and method to detect and diagnose the faults using frequency response analysis (FRA) technique. In this paper, the FRA response interpretation on internal short-circuit (SC) fault and phase-to-phase (PP) fault at two different units of three-phase induction motors is presented. The TPIMs chosen in this study were analysed based on two conditions which are, at healthy winding and with winding shorted (faulty).

2. BIBLIOGRAPHY SURVEY

TPIM faults diagnosis and detection are became extremely important due to some of serious issues such as high reliability, motors health, motors aging and cost competitiveness [10]. Among the TPIM faultsis the stator turn faults [11]. These faults occur between internal turns or coils in same phase, between turns or coils in different phases, between phase to neutral point or ground and also faults that occur because of the open circuit coil [12].There has been an interest to detect and diagnose of TPIM faults during last twenty years.

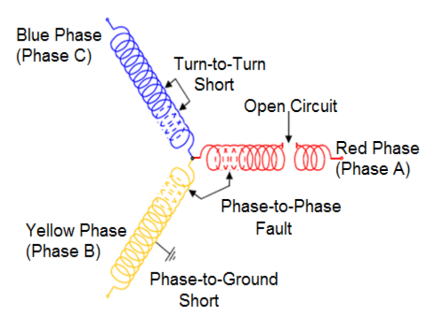


Figure 1: Induction motors common faults and Failures [12].

Table 1 summarize majority of literature on the fault detection techniques for TPIM. The references also focusingon reliable and accurate diagnosis for stator windings faults and understanding the faults causes and there effect on TPIM performances [10].

Table 1: The techniques that used for different faults detection from literaturesurvey

References	The defect that has been treated	The way used to treat the defect
[13] *Benbouzidet al., 1999*	Stator windings fault detection	Used advanced signal-processing techniques (ASPT) and stator-windings-currents
[14] *Stavrou et al., 1999* [15] *Joksimovic et al., 2000*	Inter-turn stator winding faults in IM was discussed	Detecting of the faults by used MCSA-based techniques
[16] *Thomson &Fenger, 2001* [17] *Thomson, 2001*	Internal windings short-circuit (SC) faults in TPIM was presented	Proven that short-circuit turns can detect by using motor current signature analysis (MCSA) technique
[18]*Cruz & Cardoso, 2003* [19] *Cruz et al., 2003*	Suggested a way for machine faults detection	Using the change in positive-sequence-current (PSC) monitoring by the multiple reference frame theory.
[20] *Xianrong et al., 2003*	Detect short-circuit (SC) windings faults in time domain	Statistical process control technique (SPCT) was used to detect faults
[21] *Zidani et al., 2003*	Diagnosis open-circuit (OC) faults and stator unbalance	Developed a fuzzy fault detector (FFD) by using Concordia patterns
[22] *Patel & Chandorkar, 2014*	Detection of induction motor winding fault and its location.	Discussed the performance of the TPIM and its vulnerability by modelling.
[23] *Gandhi et al., 2014*	Induction motor faults detection	Analysed the deviation in frequency response (FR) by using artificial-neural-network (ANN)
[24] *Tushar et al., 2015*	Detection of interturn fault in induction motor	Using double parks vector approach
[25] *Blnquez et al., 2015*	Detection of the electrical fault for IM field-windings was reported	Through Sweep Frequency Response Analysis SFRA technique with static excitation
[26] *Vilhekar et al., 2016*	The industrial defects causes in a structural asymmetry in IM was analyzed	Using Sweep Frequency Response Analysis (SFRA) technique
[27] *Glowacz & Adam, 2019*	Described a methods for detection stator windings fault in IM windings.	Proposed method was by using acoustic signals to analysed case study of induction motor winding

3. METHODOLOGY

3.1 TPIMs Used in The Study

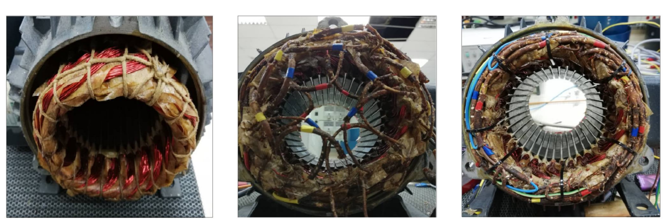
Two units of three-phase induction motorswith different rating power were chosen to conduct this study. The specifications for these units are shown in Table 2. This paper focus on the Delta (Δ) connection configuration between phases U, V and W. Therefore, phases for experimental units of TPIM windings are connected as Delta (Δ) windings configuration.

Table 2: Specifications of 3-phase induction motor units

Motor	Motor 1 Specifications	Motor 2Specification
Manufacturer	JILANG	JILANG
Model	110RK-3DS	Y90S-2
Phases	3-Ph induction motor	3-Ph induction motor
Power	0.75 KW / 1HP	1.5 KW / 2HP
Rated Voltage	415V / 50 Hz	415V / 50 Hz
RPM	1500 rpm	2840 rpm

3.2 Simulating the Faults

In this study, the artificial fault in induction motor windings are created in laboratory. These faults will be used to study their affect on winding's response that may occur due to this fault. This paper focuses on short-circuit (SC) fault and phase-to-phase turns (PPT) fault in the windings. The artificial faults created will be applied in two methods: (a) Applied only between turns of phase U to study the effect of short-circuit (SC) fault occurrence in TPIM windings, (b) Applied between single-turn in phase U with single-turn in phase V to study the effect of phase-to-phase (PP) fault occurrence in TPIM windings.The process of creating one of thefaultson TPIM are shown in Figure 2.



(a) (b) (c)

Figure 2: PPT fault processon TPIM, (a) Normal winding, (b) Removing some conductors to create the fault, (c) Completed winding with PPT fault.

3.3 Measurements Setup

In this study, FRA measurements are performed on phases U, V and W to diagnose and detect fault in TPIM windings. The measurements were performed before and after the fault has created. Windings frequency responses are analyzed and interpreted by comparing both responses. It can be noted that FRA test is a reliable method for faults detection in many part of transformers including transformer windings as presented in previous papers [28], [29].

(a) (b) (c)

Figure 3: Equipment connection (a) Computer, (b) FRANEO 800 equipment, (c) Three-phase induction motor

In this study, the measurement procedure was based on Delta (Δ) configuration of TPIM between phases U, V and W. With this type of connection, the frequency responses are measured between phase terminals (U-V, V-W, and W-U) only. Figure 3 shows connection between the equipment which are used to perform the FRA measurements.

4. FRAMEASUREMENTS

In this section, the results of FRA response for both short-circuit (SC) and Phase-to-phase (PP) faults are presentedand discussed.For each case of fault,frequency response was measured between phase terminals (U-V, V-W, and W-U) at two condutions: during healthy windings condition and at (SC and PP) faults occured in the TPIM stator windings. Figure 4shows the frequency responses curves for both TPIMs tested. As shown in figure, the responses were different between each other. This is mainly due to different size and construction of each motor that used in this study.

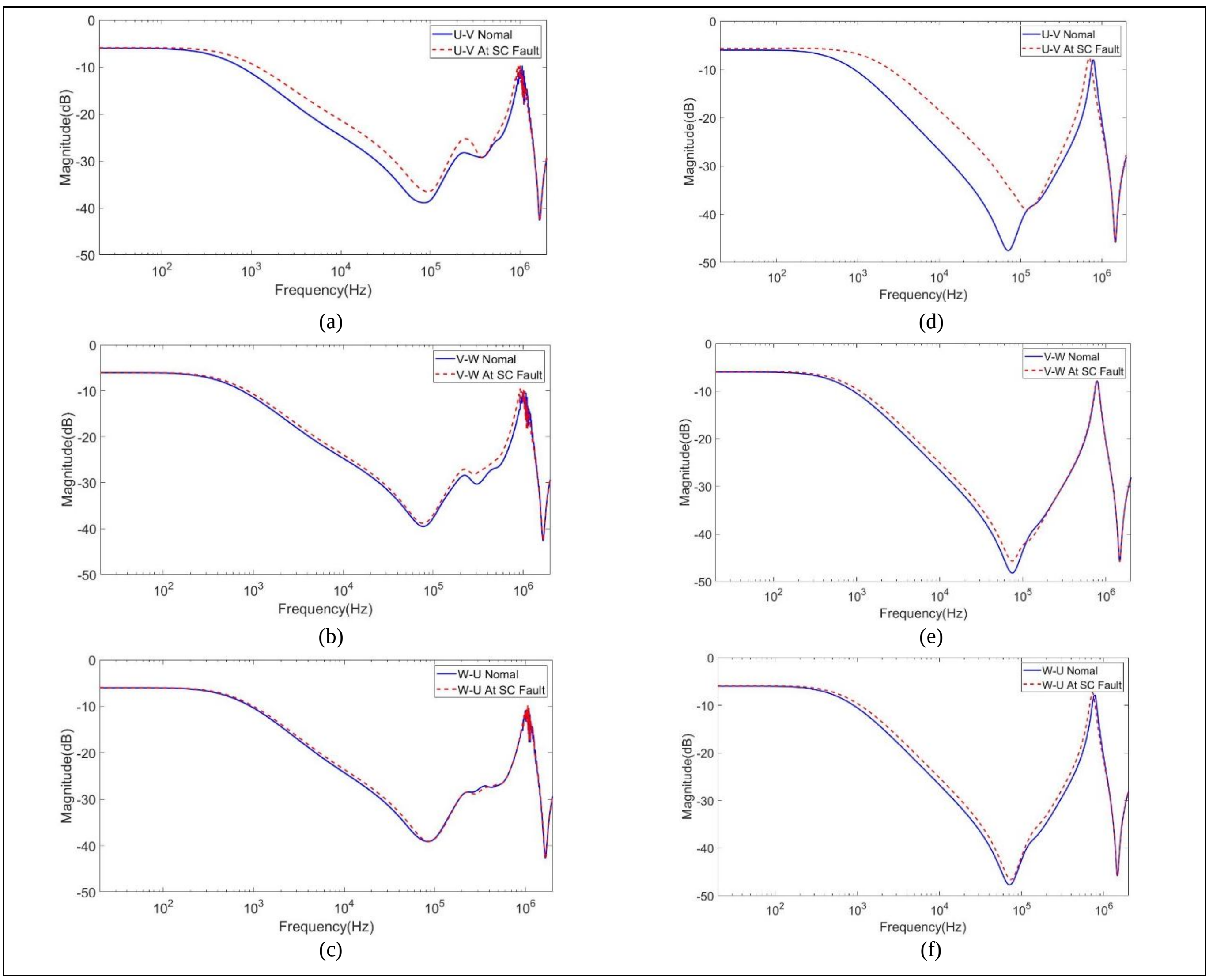


Figure 4: FRA Measurement at (SC) fault. (a) U-V of 1HP TPIM, (b) V-W of 1HP TPIM, (c) W-U of 1HP TPIM (d) U-V of 2HP TPIM, (e) V-W of 2HP TPIM and (f) W-U of 2HP TPIM

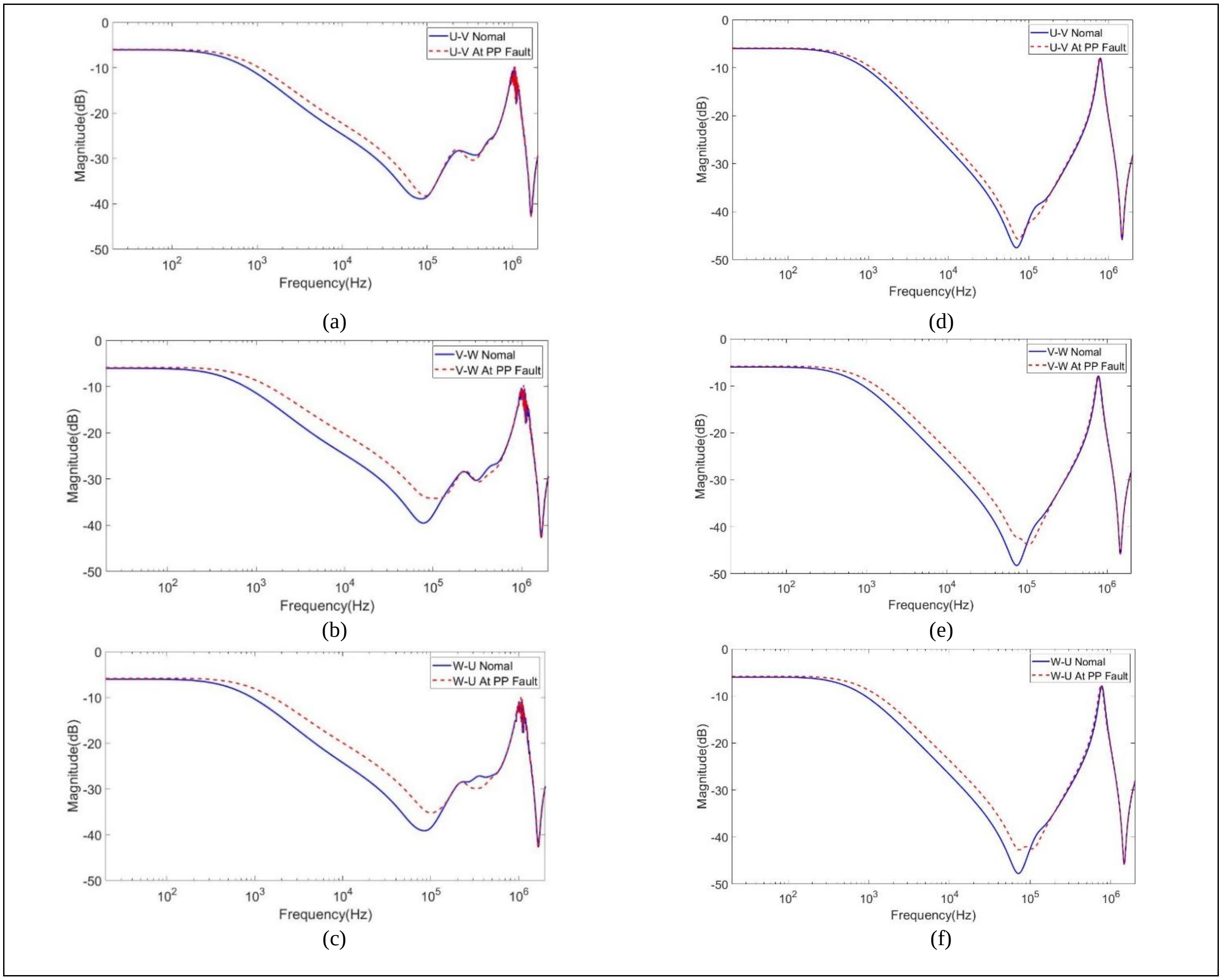


Figure 4: FRA Measurement at (PP) fault. (a) U-V of 1HP TPIM, (b) V-W of 1HP TPIM, (c) W-U of 1HP TPIM (d) U-V of 2HP TPIM, (e) V-W of 2HP TPIM and (f) W-U of 2HP TPIM

The effect of these two faults leads to short circuit condition in the electrical windings. This decreases the coil length which is basically the number of turns will be less than the normal condition. For this reason, the overall resistance of each winding phase will decreases. Therefore, during (SC) fault the shorted turns that shorted to create the fault will lead to reduction of inductance in phase U. These faults causes change in response as shown in Figure 4 and Figure 5. In Figure 4, the comparison of FRA at both cases of normal condition and at SC winding fault shows it affecting the response according to measurement connection which was measured between terminals (U-V, V-W, and W-U). The responses measured at terminals U-V at SC fault condition showed large variation on the response for both TPIMs as shown in Figure 4 (a) and (d). From other hand, the responses measured at terminals V-W and W-U were also affected by the fault. However, the variation on these two responses (V-W and W-U) were less than in U-V response as shown in Figure 4 (b), (c), (e) and (f).

Phase-to-phase (PP) fault occurrence has the same effect as (SC) fault term of reducing the overall winding resistance and inductance. This is largely affecting in phase U and phase V, because of the shorted turns occurred between phases U and V. For this reason, the response will change magnitude and frequency and this considered as defective response. The comparison of responses between normal condition and at PP fault given in Figure 5.The responses show the effect of PP fault according to the measurements connections conducted for terminals U-V, V-W and W-U. The changes of response between the reference responses and the responses were very evident at PP fault condition for terminals V-W and W-U as shown in Figure 5 (b), (c), (e) and (f). This is because the PP fault was created in phases U and V windings. Also due to effects of delta (Δ) connection between phases U, V and W. For response of terminals U-V, the changes of response was relatively small as shown in Figure 5 (a) and (d). This is because of the fault was in side of phase U or V windings with the healthy phase W from the other side.

5. CONCLUSION

This paper presented the interpretation of FRA signature due to two different stator winding faults of 3-phase induction motor. These are short-circuit (SC) fault and phase-to-phase (PP) fault. From the results of this paper, the comparison of frequency responses proven that the SC and PP faults in stator winding of TPIM gives some of variation in the FRA response. The findings of this study also show detection and diagnosis of the faults occurred in one phase only at SC fault condition and the faults occurred in two phases which is PP fault condition. This is through the variation between the FRA responses of phases when measured the frequency response. The proposed method in this paper had a useful findings proven the ability of FR Ato detect and diagnose of SC fault and PP fault of stator windings of TPIM.

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