Contactless Measurement Method for HDD Spindle Motor Parameters

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***Abstract*--Conventional method of measuring inductance involves using a R-L-C meter. Such measurement method has limitation on accuracy due to the interference of back EMF during rotation. Profiling of the inductance at various motor positions thus requires cumbersome mechanical locking of the rotor. In this paper, an elegant method is introduced to capture inductance profile of spindle motor without the need for mechanical locking. The method involves using a DC electrical locking signal super-positioned with a pulse measuring signal to perform the measurement. The DC locking signal is then made sweep to allow micro-stepping of the motor so that inductance profile could be captured at all rotor position. The proposed method is shown to be effective, supported by derivations and experimental results**

Index Terms—**BLDC, PMSM, Resistance, Inductance, Measurement**

I. INTRODUCTION

In the initiation of higher energy savings, and power efficiency has lead to the popularity of the Permanent Magnet Synchronous Motor (PMSM). Today, the PMSM is widely used in numerous industrial applications, such as HDDs, where high speed operation, precise torque control and high power density are required [1].

In the adoption of PMSMs, it is necessary to parameterize the motor resistance and inductance in usage. Conventional method that involves a R-L-C meter requires a mechanical fixture during the measurement process [2]. This technique is inefficient especially when inductance profile of the motor at various positions is required.

In this paper, an elegant method to capture the inductance profile of the motor is presented. The measuring method involves using a novel way to calculate inductance while ensuring the motor remains electrically locked. Firstly, micro-stepping and locking of the PMSM motor is investigated. Subsequently, a novel method to lock the motor while injecting pulse current for measurement is illustrated. Lastly, based on the above prerequisites, a rise-time method is used to determine resistance and inductance profile.

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II. MICRO-STEPPING OF PMSM

In order for the inductance to be dutifully captured in each positions of the motor, the measuring system must be capable of rotating in fixed intervals during each measuring cycles As such micro stepping of the PMSM would be essential for inductance profiling of the PMSM motor.

To achieve this, on the assumption of a balanced three phase windings, the rotating magnetic field produced by slow time-varying (almost DC) displaced currents is utilized for micro-stepping.

III. PARAMETERS MEASUREMENT

The reliance using slow time-varying locking current however causes another problem for inductance measurement of the PMSM. It is important to ensure that the significantly large locking current must not interfere in the measurement process. This problem can be overcome by super-positioning a faster time varying measurement signal onto the locking signal during measurement. However, in the process of locking, all three terminals are driven, how then can one direct the measuring signal into the correct phase? To remedy this, a choke is then used to direct the AC measuring signal to the correct windings for measurement. A simplified circuit model depicting how the motor inductance is measured is shown in Fig. 1.

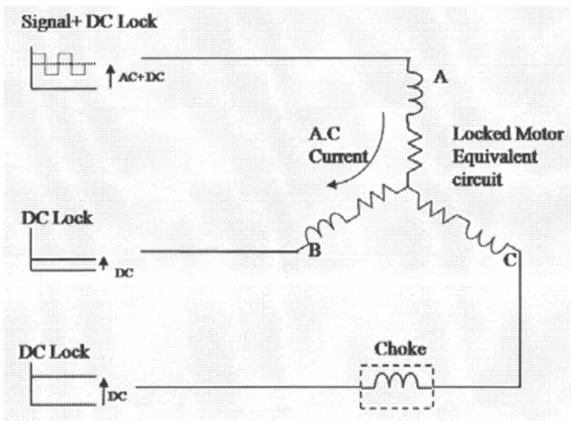

Fig. 1. Simplified Circuit Model for Measurement of Phase AB.

With the measuring pulse current flowing only through windings A and B, and winding C becomes an open circuit, the parameters can be given by

$$R_{ab} = (V_p / I_p) \quad (1)$$

$$L_{ab} = (t_{rise} R_{ab} / 3) \quad (2)$$

where R_{ab} is the sum of phase resistance R_a and R_b
L_{ab} is the sum of phase inductance L_a and L_b
V_p is peak-peak of the measuring signal
I_p is peak-peak of the measuring current
t_{rise} is rise-time to 95% of I_p

IV. EXPERIMENTAL RESULTS

The system uses Xilinx V4FX12LC FPGA board and a peripheral circuit board for physical implementation of the hardware.

Fig. 2 shows the terminal voltage waveforms where by the measuring signal imposed onto phase A, AC ground with phase B and phase C choked block. Fig. 3 shows the zoomed in plot for the applied measuring signal with its corresponding current. At each positional step, motor parameters can be calculated as in equation (1) and (2). Fig. 4a shows the plot of inductance profile for an electrical cycle where as Fig. 4b shows the inductance profile obtained using RLC meter and mechanical lock. The benefit of using the measuring system is obvious. A higher step-resolution could be achieved using the automated measuring device. In addition, the time required to determine the inductance profile of the PMSM is decreased drastically.

V. CONCLUSIONS

In this paper, an automated parameter profiling system is proposed. This system comprises of (1) micro stepping control of PMSM (2) parameters measurement using super-imposed measuring signal. The proposed method is effective and is comparable to manual measurement using R-L-C meter. The benefits of using such measurement method increase step resolution and reduces measurement time for parameterization.

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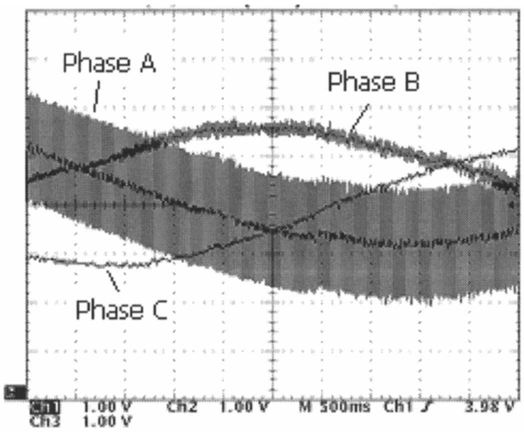


Fig. 2. Terminal Voltage Waveform. Measuring Signal is applied on Phase A with phase C blocked by choke

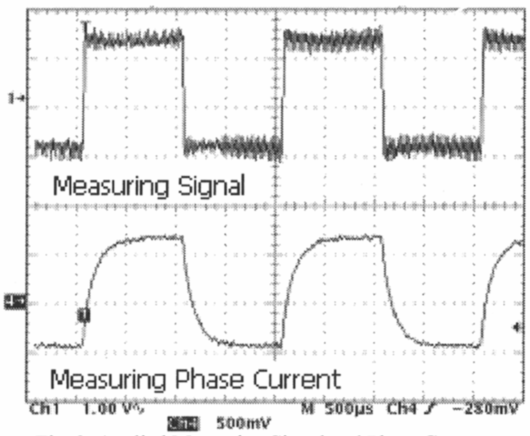
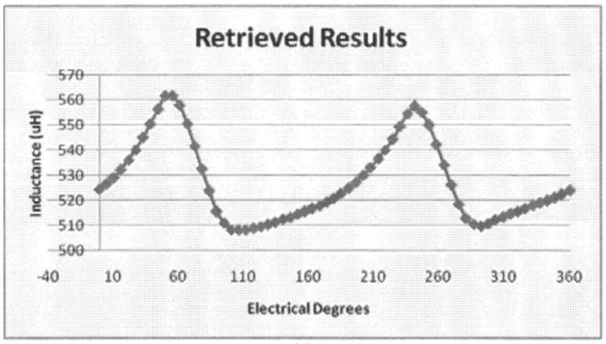
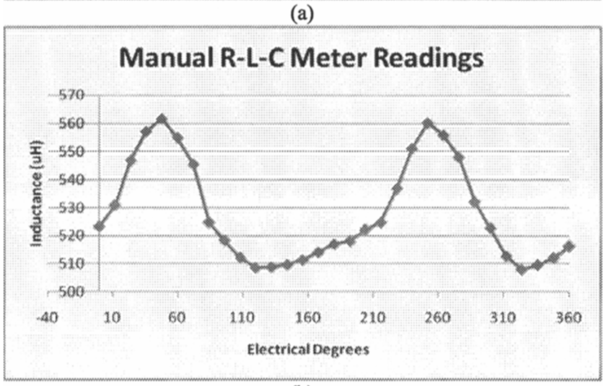


Fig. 3. Applied Measuring Signal and Phase Current



(a)



(b)

Fig. 4. Comparison between (a) Retrieved results from proposed method (b) Manual results from using a R-L-C meter.