Analysis of Torque Performance A High Speed PM Synchronous Motor using v/f Control with Current Angle Tracing Concepts

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Abstract — In general, V/f control has been used in induction motor. But V/f control methods can be used to control also, when permanent magnet synchronous motors(PMSMs) are used for pump and fan applications. The V/f control, which realizes a low cost and simple design, is advantageous in the middle to high speed range.
When we control synchronous motors, in order to promote efficiency, we must take a power factor degree, that is changed because of inductor, resistance and frequency, in the motor. Therefore in this paper a comparison power factor degree, when consider power factor degree and out of consideration power factor degree, is proposed for motor drives on stable operation by V/f control.

I. INTRODUCTION

Recently, the demand for high-speed motors has increased recently due to the technology advance and cost reduction in the power electronic, permanent magnets material, and motor design[1].
In general, the control approaches used most commonly in permanent magnet synchronous motors(PMSMs) control are scale control, vector or field-oriented control and direct torque control, and V/f control has been used in induction motor[2][3]. But V/f control methods can be used to control also, when motor drives are used for appliances like pumps and fans where high dynamic performance is not a demand, a simple constant V/f control method is the most popular method of control because the V/f control, which realizes a low cost and simple design, is advantageous in the middle to high speed range[4]. But electro-magnetic performances are affected by power factor angle and ratio of voltage and frequency. Thus, in this paper deals with influence by ratio of voltage and frequency, and the need for considering power factor angle under V/f control.

II. TORQUE CHARACTERISTIC ANALYSIS OF V/F CONTROL

In this paper, first, the manufactured model is suggested by Figure 1(a), shows the manufactured model of the PMSM which has stator with winding and housing. Fig. 1(b) shows the PMSM which consists of shaft, high speed ball bearing and sleeve for protect against the centrifugal force with a nonmagnetic retaining sleeve, and then the electromagnetic field analysis is performed by analytical method, and the circuit parameters are calculated, such as back-EMF

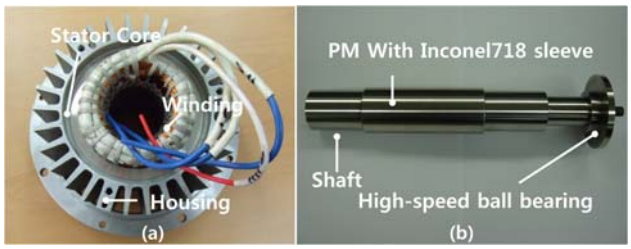

Fig. 1 Manufactured model. (a)Stator (b)Rotor

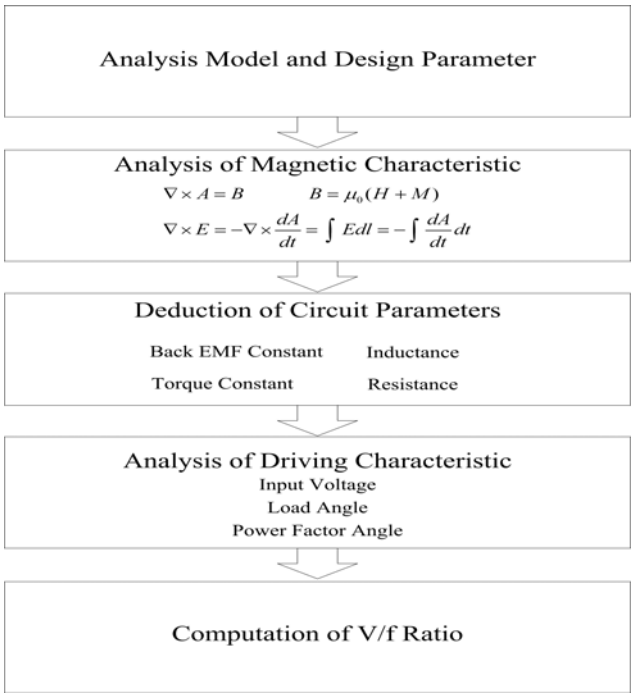

Fig. 2 Procedure of analysis

constant, resistance and inductance from the analytical solution obtained from finite element(FE) analysis and the transfer relation theorem(TRT). Then power factor angle and input voltage are calculated from the electrical parameters, and Fig. 2 shows the procedure of analysis.
In general, V/f control is not considered current angle that varied by load angle, and it is just driven by calculated V/f ratio. Therefore, in this paper compared of two cases of torque characteristic. Case 1 is considered calculated input voltage and power factor angle, and not considering power factor angle that fixed power factor angle at rated, case 2.

$$\phi = -\tan^{-1}\frac{\omega L_s V_s + R_s E_f \sin\delta - \omega L_s E_f \cos\delta}{R_s V_s - R_s E_f \cos\delta - \omega L_s E_f \sin\delta} \qquad (1)$$

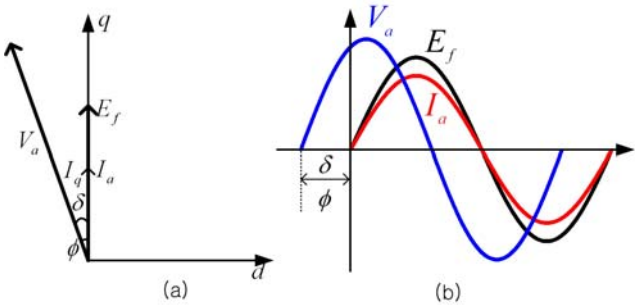

Fig. 3 For occurrence max torque, (a)phase diagram and (b)phase relation.

Power factor angle is defined by (1), and $\omega, V_s, L_s, R_s, E_f$ and δ are defined angular speed, rated voltage, synchronous inductance, resistance, back EMF and load angle, respectively. Current angle is difference that back EMF by PM and current, to zero current angle, d-aixs current is must zero as shown as Fig. 3(a), and Fig. 3(b) shown as phase relation with input voltage, back EMF and current, but load angle is changed by frequency, so load angle that in order to zero current angle is must considered by each frequency[5][6].

III. RESULT

This paper deals with analysis of performance a high speed permanent magnet synchronous motor by v/f Control. Fig. 3(a) shows the calculated load angle that in order to zero current angle at each frequency with fixed load angle on each frequency, and Fig 3(b) shows the phase angle of induced voltage and output current when considering ratio of input voltage and frequency at rating and power factor angle. As shown in Fig. 3(c), there is the compared torque performance of case1 and case2.As a result of the case1 is higher torque then case2 at low frequency.

The more detailed analysis results, discussion and mathematical expressions will be given in final paper.

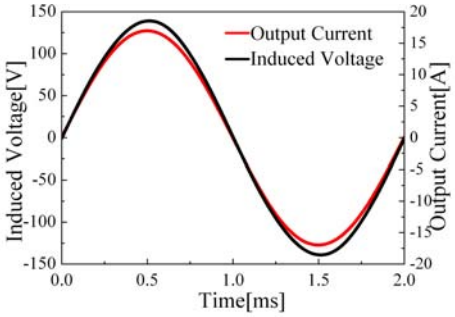

Fig. 4 Comparison with input voltage and back EMF, for zero current angle.

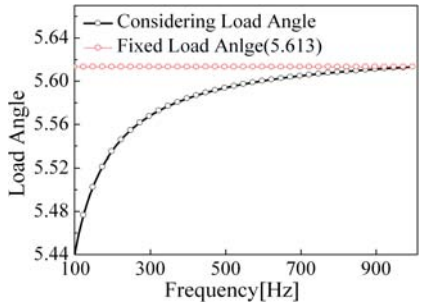

Fig. 5 To zero current angle, calculated the load angle.

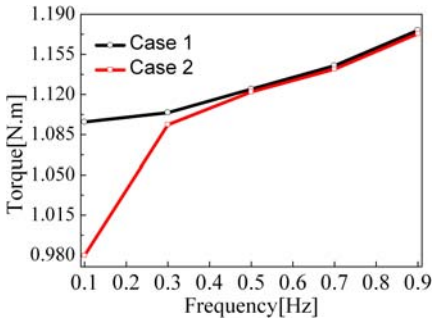

Fig. 6 Comparison of case1 and case2 on torque.

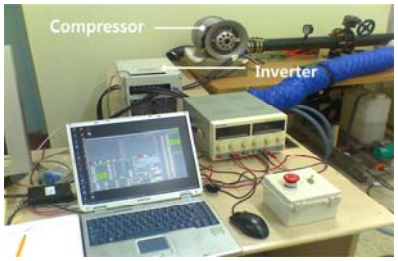

Fig. 7 shows the experimental setup for a manufactured PMSM.

IV. REFERENCES

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