Basic Motor Parameters and the Configuration

About this document

Scope and purpose

This document provides how to measure the basic motor parameters that required for the iMOTION™ FOC algorithm, and how to configure them in the Config Wizard in iMOTION™ Solution Designer (iSD).

Intended audience

The intended audience for this document is all iMOTION™ users.

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1 Introduction

iMOTION™ is a family of integrated products for the control of permanent magnet (PM) motors that combine industry proven hardware and ready to use software.

These devices are capable of performing sensorless or sensor-based Field-Oriented Control (FOC) across the entire speed range of the motor, ensuring stable control. The iMOTION™ software, deployed onto the hardware devices, is referred to as Motion Control Engine (MCE). A PC tool called the iMOTION™ Solution Designer (iSD) is available for the configuration, validation, deployment and user script code development. In order to use iMOTION™ FOC algorithm, the user must enter the basic motor parameters in the Configuration Wizard in iSD.

Some of the basic motor parameters such as stator resistance, inductance, pole numbers and Back EMF values need to be measured on the actual motor to be used using an LCR meter or oscilloscope. This application note describes how to measure these basic motor parameters manually. It also explains how to configure these parameters in iSD.

2 Motor Parameters required in MCE

The Table 1 shows the motor parameters required for MCE control. The parameters in bold character are what users have to measure manually.

Table 1 Motor parameters required for MCE.

Parameter Name	Descriptions
Motor nominal voltage	This parameter specifies to the motor maximum terminal voltage. This parameter is commonly printed on the motor label.
Rated power	This is the Maximum mechanical power required to drive the load.
Motor rated amp per phase	This parameter specifies the continuous RMS current rating of the motor. This parameter is commonly printed on the motor label.
Motor poles	This parameter specifies the number of magnetic poles in a full mechanical cycle. This parameter is commonly printed on the motor label. However, it can be measured easily by using oscilloscope.
Maximum speed	Maximum motor speed when running. This parameter is commonly printed on the motor label.
Minimum speed	Minimum motor speed when running. When using flux estimator angle feedback, the recommended minimum speed is between 5% and 10% of the maximum speed.
Stator resistance per phase (R_s)	This input specifies the per phase winding resistance of the motor.
IPM motor stator l_q inductance per phase	The quadrature-axis (Torque current) inductance of each phase winding.
IPM motor stator l_d inductance per phase	The direct-axis (Flux current) inductance of each phase winding.
Motor back EMF constant per 1000 RPM	This parameter specifies the line-neutral back EMF constant expressed in volts RMS per 1000RPM.

The major motor parameters are printed on the motor label as shown in **Error! Reference source not found.**, but basic motor parameters such as stator resistance, inductance, and Back EMF values are generally not printed on the label. Therefore, users have to measure these parameters manually by using an LCR meter or oscilloscope. The measurement methods for these parameters are explained in the following section.

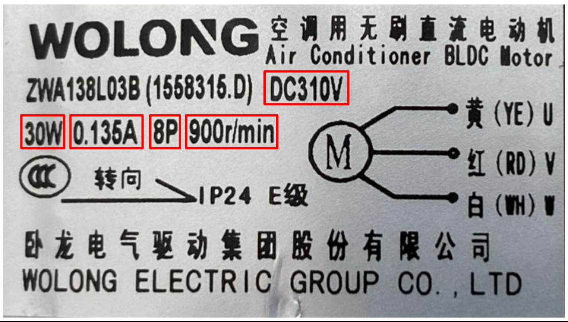

Figure 1 Motor label example

3 Measure the Basic Motor Parameters

In this section, it is explained how to measure basic motor parameters as listed below. Regarding the parameter of the Motor poles, it is commonly printed on the motor label, but it is better to measure on the actual motor for double check.

- Stator resistance per phase (R_s)
- Stator inductance per phase (l_q, l_d)
  - IPM motor stator lq inductance per phase
  - IPM motor stator ld inductance per phase
- Motor poles (p)
- Motor back EMF constant per 1000 RPM (K_e)

3.1 Stator Resistance (R_s)

Figure 2 shows the measurement method of the stator inductance with the equivalent circuit of the motor. It measures the line-to-line resistance by LCR meter, but this measurement result is the sum of the two resistances of both lines. The MCE parameter of a stator resistance parameter (R_s) represent the winding resistance of the motor per phase, so the measurement result should be divided by 2.

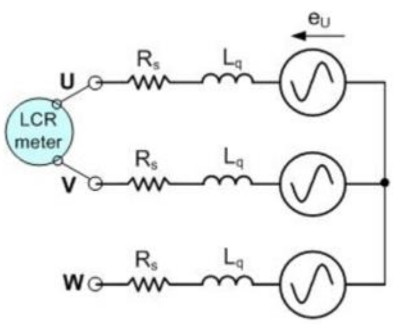

Figure 2 Measurement method of Stator Resistance (R_s) and Stator Inductance (L_q, L_d)

3.1.1 Measurement procedure

The measurement procedure of R_s is as follows,

1. Connect 2 phases to LCR meter, and leave third phase open
2. Measure the line to line resistance value
3. Divide the measured resistance value by 2

3.1.2 Measurement example

Figure 3 shows the actual measurement example of the line to line stator resistance. The measurement result in this example is the 94.28 Ω, so, the parameter value of the R_s is 47.14 Ω.

Figure 3 Measure Line to Line Stator Resistance ($2R_s$)

3.2 Stator Inductance (L_q, L_d)

An advanced sensorless Field Oriented Control (FOC) algorithm in the MCE supports two motor types such as surface mounted permanent magnet (SPM) motors and interior permanent magnet (IPM) motors.

When working with surface permanent magnet (PM) motors the winding inductances L_d and L_q will have the same value with any rotor angle as shown in Figure 4, left. However, when working with interior permanent magnet (IPM) motors the winding inductance varies with the rotor angle as shown in Figure 4, right, and the L_q inductance is greater than the L_d inductance.

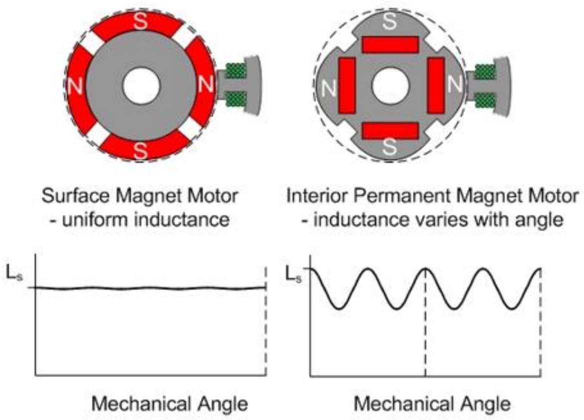

Figure 4 Motor type (PM motor, IPM motor)

This section explains how to measure the winding inductance values L_q and L_d when using a 4-pole IPM motor.

Figure 2 shows the measurement method of the stator inductance with the equivalent circuit of the motor. It measures the line-to-line inductance by LCR meter, but this measurement result is the sum of the two inductances of both lines. The MCE parameter of a stator inductance parameter (L_q or L_d) represents the winding inductance of the motor per phase, so the measurement result should be divided by 2.

And since the inductance value of the IPM motor varies with the rotor angle, it is necessary to adjust the angle to measure the L_q and L_d value. Figure 5 shows the inductance value of the 4 pole IPM motor with respect to the electrical angle and the mechanical angle. With respect to the 4 pole motor, one cycle of the electrical angle is half cycle of the mechanical angle. And there are 4 peaks (maximum and minimum) in inductance value in one electrical cycle. So, it means that the inductance value is changed from maximum to bottom between 45 degrees in the mechanical angle. Therefore, to measure the inductance value with changing the motor angle gradually by hand within 45 degrees in the mechanical angle, and the maximum value is the L_q, and the minimum value is the L_d.

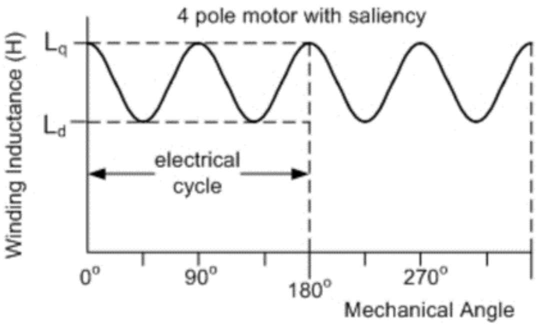

Figure 5 Stator Inductance (L_q, L_d)

3.2.1 Measurement procedure

The measurement procedure of L_q and L_d is as follows,

1. Connect 2 phases to LCR meter, and leave third phase open
2. Measure the line to line inductance value
3. Rotate the rotor gradually by hand and record the highest inductance value as L_q, and the lowest inductance value as L_d
4. Divide these measured inductance values by 2

3.2.2 Measurement example

Figure 6 shows the actual measurement example of the line to line stator inductance. The measurement result of L_q is shown on the right, and L_d on the left. The measurement result of the L_q is the 550.0 mH, so, the stator inductance per phase is 275.0 mH. The measurement result of the L_d is the 469.0 mH, so, the stator inductance per phase is 234.5 mH.

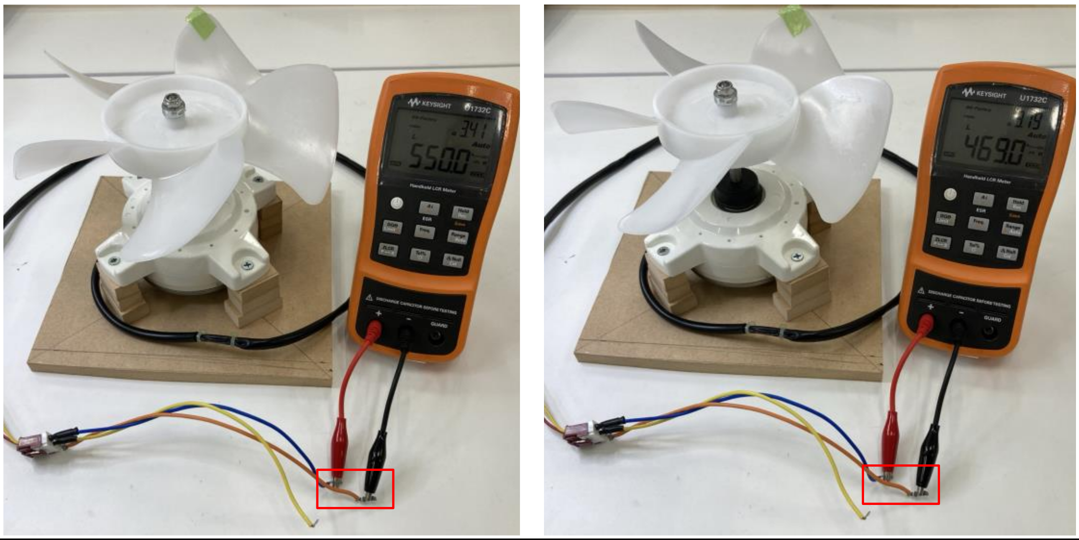

Figure 6 Measure Line to Line Stator Inductance ($2L_d$, $2L_q$)

3.3 Motor Poles number (p)

This parameter represents the number of magnetic poles in a full mechanical cycle. There is one electrical cycle for every pair of magnetic poles.

This parameter can be identified by counting the positive and negative peaks in the motor back EMF waveform over a full mechanical revolution.

Figure 7 shows the line-to-line voltage waveform generated by the back EMF of the 4 pole IPM motor. There are 2 peaks and 2 valleys (2 sinusoidal shaped cycles) in one mechanical cycle.

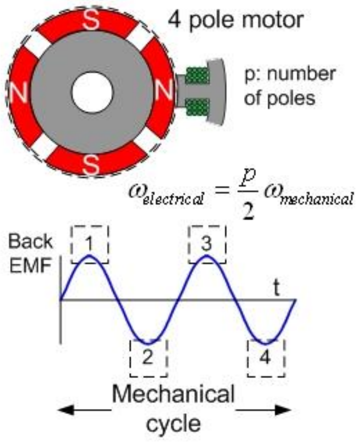

Figure 7 Measurement method of Motor poles number

3.3.1 Measurement procedure

The measurement procedure of motor poles number is as follows,

1. Connect 2 phases to oscilloscope voltage probe, and leave third phase open
2. Move the motor by hand at a constant speed and make one mechanical revolution, and record the waveform by oscilloscope
3. Count the peaks of sinusoid

3.3.2 Measurement example

Figure 8 shows the actual measurement example of the motor pole number, and the measurement result is shown in Figure 9. There are 8 peaks in one mechanical angle, so it is identified as 8 pole.

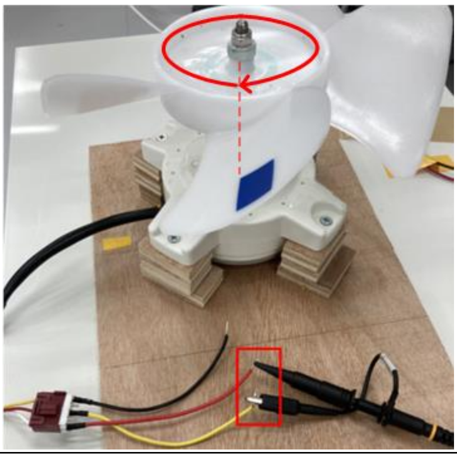

Figure 8 Measure Motor poles number

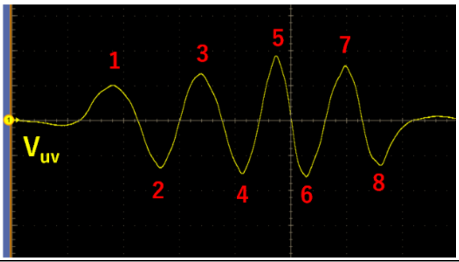

Figure 9 Measurement result of the Motor poles number (p)

3.4 Motor Back EMF constant (K_e)

This parameter represents the line-neutral back EMF constant expressed in RMS phase voltage (E_U) when the motor speed is 1000 RPM.

K_e can be determined experimentally by driving the motor, measuring the line-to-line peak voltage and calculate the actual back EMF. Figure 10shows the measurement method of the K_e with the equivalent circuit of the motor.

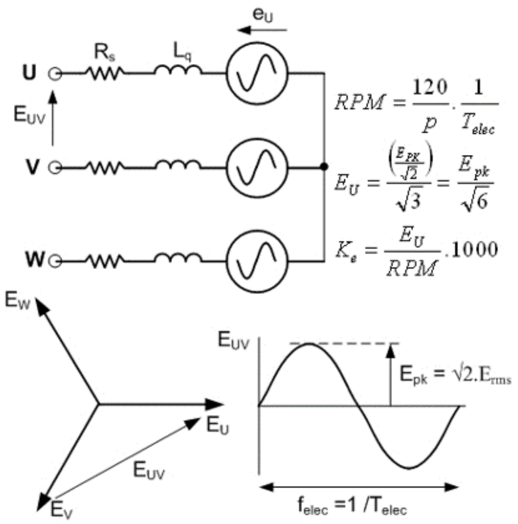

Figure 10 Measurement method of Back EMF constant (K_e)

From the definition of K_e, K_e is expressed by the following equation.

$$K_e = \frac{E_U}{RPM} \cdot 1000$$

RPM and E_U are expressed by the following equations.

$$RPM = \frac{120}{p} \cdot \frac{1}{T_{elec}} \qquad E_U = \frac{\frac{E_{pk}}{\sqrt{2}}}{\sqrt{3}} = \frac{E_{pk}}{\sqrt{6}}$$

Where, p is pole number, T_{elec} is electrical angle period of time, E_{pk} is peak line-to-line voltage (amplitude). The phase voltage E_U is expressed as the RMS value of the line-to-line voltage divided by the square root of 3, and the RMS value of the line-to-line voltage is expressed as the amplitude E_{pk} divided by the square root of 2.

Substituting these equations into K_e's equation gives and expands as shown in Equation 1.

$$K_e = \frac{E_U}{RPM} \cdot 1000 = \frac{E_{pk} \cdot p \cdot T_{elec} \cdot 1000}{120 \cdot \sqrt{6}}$$

Equation 1 Equation of Back EMF constant (Ke)

3.4.1 Measurement procedure

The measurement procedure of the K_e is as follows,

1. Connect 2 phases to oscilloscope voltage probe, and leave third phase open
2. Turn the rotor by hand at a constant speed, and record the waveform by oscilloscope
3. Measure the E_{pk} voltage, and the T_{elec} by cursor
4. Calculate the K_e value by Equation 1 (The pole number is assumed to be known, if not please refer to section 3.3.)

3.4.2 Measurement example

Figure 11 shows the actual measurement method of the K_e, and the measurement result is shown in Figure 12. In this example, p is 8 poles, E_{pk} is 33.64 V, and T_{elec} is 62.27 ms, so by substituting these parameters into the Equation 1, K_e is derived as 57.01 Vrms/kRPM.

$$K_e = \frac{E_U}{RPM} \cdot 1000 = \frac{E_{pk} \cdot p \cdot T_{elec} \cdot 1000}{120 \cdot \sqrt{6}} = \frac{33.6V \cdot 8 \cdot 62.27ms \cdot 1000}{120 \cdot \sqrt{6}} = 57.01\, Vrpm/kRPM$$

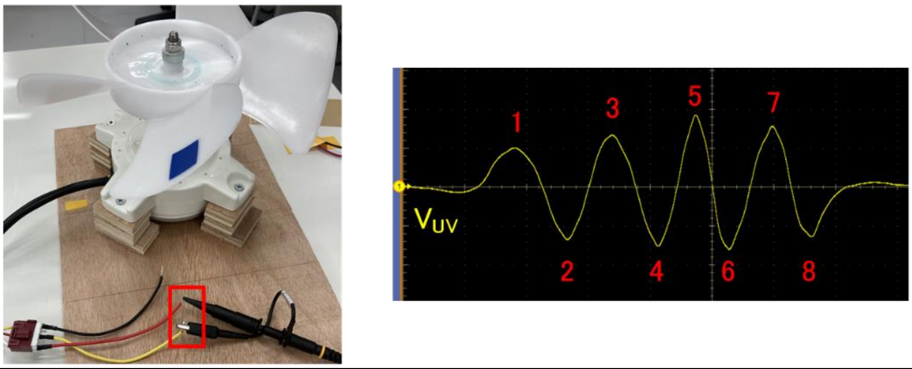

Figure 11 Measure Motor poles number and K_e

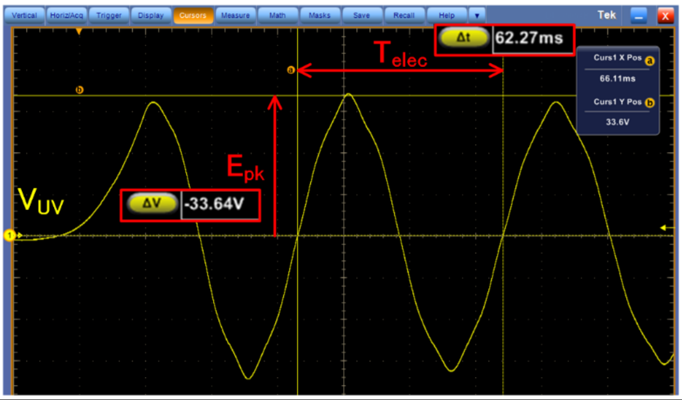

Figure 12 Measurement result of back EMF constant (K_e)

4 Configure the Motor Parameters in iSD

This section explains where to enter the basic motor parameters in the Configuration Wizard Window in iSD. Motor parameters are categorized in the "Motor" section in the System Hardware Configuration parameter group. Figure 13 shows the "Motor" section page in Configuration Wizard Window.

The motor parameters measured in the previous section are listed below, and the corresponding items in the Configuration Wizard are shown in the Figure 13.

1. Stator resistance per phase (R_s): 47.14 Ω
2. Motor poles (p): 8 poles
3. IPM motor stator l_q inductance per phase (l_q): 275.0 mH
4. IPM motor stator l_d inductance per phase (l_d): 234.5 mH
5. Motor back EMF constant per 1000 RPM (K_e): 57.01 Vrms/kRPM

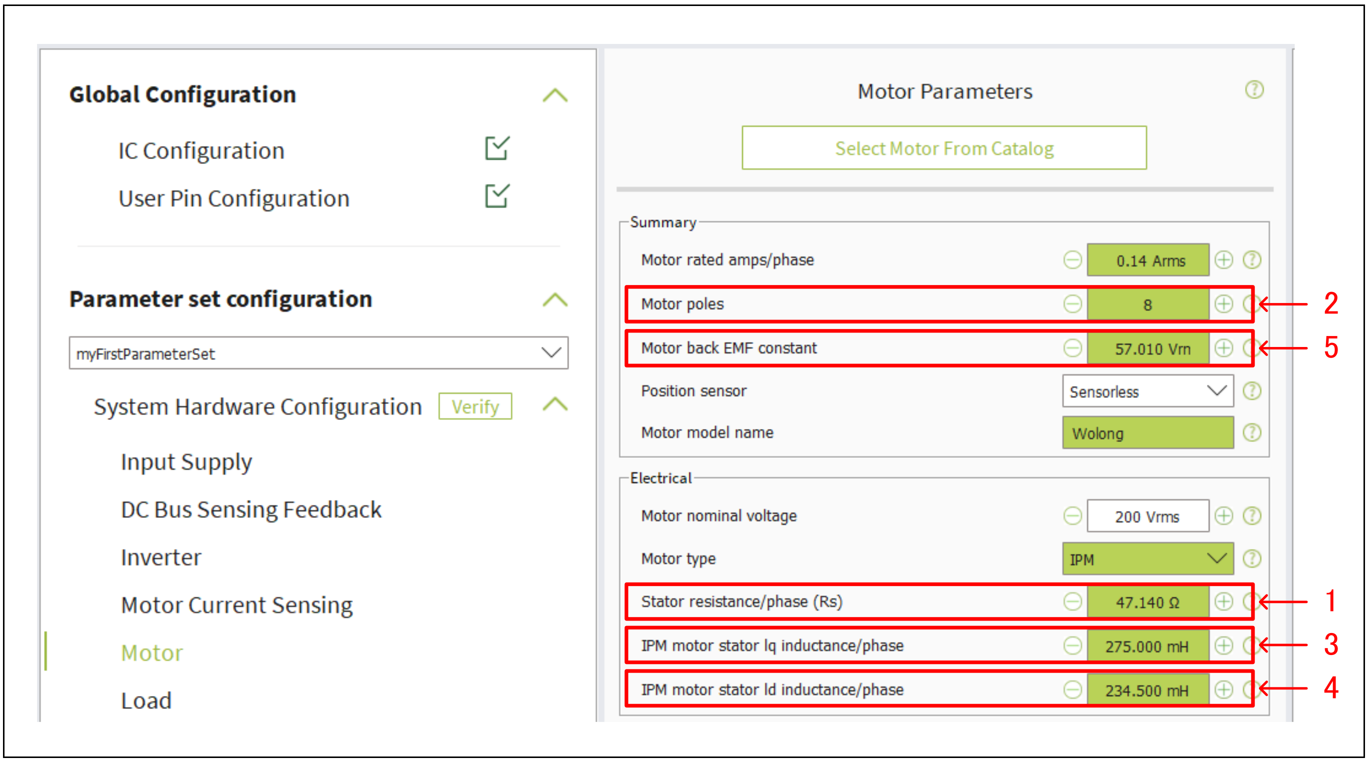

Figure 13 Motor parameter section in Configuration Wizard

References

[1] Getting Started with iMOTION™ Solution Designer

[2] iMOTION™ Solution Designer User Guide

Revision history

Document revision	Date	Description of changes
1.0	2023-12-14	Initial Release

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Edition 2023-12-15

Published by

Infineon Technologies AG

81726 Munich, Germany

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Document reference

AN2023-10