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APPLICATION NOTE

Drive Applications Support Library

Application Note	AN-P2-050
Title	Permanent Magnet & Brushless DC Motor Setup
Related Products	P2 Series AC Drives
Level: 3	<ul style="list-style-type: none"> 1 - Fundamental - No previous experience necessary. 2 - Basic - Some basic drives knowledge recommended. 3 - Advanced - Some basic drives knowledge required. 4 - Expert - Good experience in topic of subject matter recommended.

Overview:

The P2 series drive is capable of operating with both AC Permanent Magnet (PM) and Brushless DC (BLDC) motors. This control is achieved open loop – without needing any feedback sensor connected to the motor. PM and BLDC motors generally offer improved efficiency with reduced size compared to standard induction motors.

This application note details the parameter settings and process for set up when using either PM or BLDC motors, and provides some guidance on trouble shooting problems when using either type of motor.

The procedure for using either type of motor is the same, except for the motor type selection in parameter P4-01. As such, this application note is applicable to both types of motor.

This application note assumes that the reader is familiar with the operation of Sensorless Vector Control with standard induction motors, understands the principles of adjusting application related tuning parameters such as acceleration and deceleration times and is familiar with the principles of tuning the speed loop for optimum performance.

Key motor Parameters Required for Operation:

P1-07 Motor Rated Voltage

This parameter must be set to the motor Back EMF at rated speed, often referred to as motor nominal voltage (UN). This is the Back EMF value which will be imposed by the motor magnets at the drive output terminals when the motor operates at rated speed.

Many motor manufacturers will provide this data in different formats, and some calculation may be required to find the actual value to be used for this parameter. The value entered must be the phase to phase voltage. Phase voltages (phase – neutral) must be multiplied by $\sqrt{3}$ (1.732) and the resultant value entered into P1-07

In some cases, the motor manufacturer will supply a voltage constant, e.g. 50 Volts / 1000 Rpm. In this case, the voltage constant should be multiplied by the rated speed to determine the correct value, e.g. if the motor is has a rated speed of 3000 Rpm, and a voltage constant of 50 Volts / 1000 Rpm, $P1-07 = 3000 / 1000 \times 50 = 150$ Volts.

P1-08 Motor Rated Current

This parameter must be set to the motor continuous rated phase current in amps, often referred to as the motor nominal current (IN). This parameter is used to protect the motor and prevent damage through excessive current.

P1-09 Motor Rated Frequency

This parameter must be set to the frequency required for the motor to operate at rated speed, often referred to as the motor nominal frequency (fN). If the actual frequency is not given, it may be determined from the motor pole count as follows:

Rated Frequency = Motor Rpm x Motor Poles / 120 E.g., 8 pole motor, 3000 Rpm rated speed

E.g., 8 pole motor, 3000 Rpm rated speed

Rated Frequency = $3000 \times 8 / 120 = 200\text{Hz}$

P1-10 (Optional) Motor Rated Speed (RPM)

This parameter should be set to the rated speed of the motor, often referred to as the motor nominal speed (nN). The speed must be the speed at which the motor operates when the frequency set in P-09 is applied.

P2-24 Effective Switching Frequency

For PM motor applications, it is recommended to use an effective switching frequency of at least 16kHz. Setting of the drive output switching frequency is a compromise between smoothest possible operation and minimization of drive losses (with the potential need to de-rate the drive). Some testing may be required to establish the lowest switching frequency (minimum 16kHz) that can be selected whilst maintaining the required level of performance. When increasing switching frequency setting always consult the appropriate drive de-rating data and configure parameter P1-08, Motor rated current, appropriately.

P4-01 Motor Type Selection

This parameter allows selection of the correct motor type and control method. Note that P4-01 cannot be accessed unless extended or advanced parameter access is enabled – refer to the drive user guide for further information.

The default setting of P4-01 is 2, V/F control for induction motors.

For AC PM Type Motors, this should be set to 3.

For BLDC Motors, setting 5 must be used.

P4-02 Motor Data Auto tune

When the above parameters have been set, an autotune must be carried out. For correct operation, accurate motor data is required, which can only be determined through the autotune.

Autotune is carried out by setting P4-02 = 1. The drive will display “Auto-t” and the motor data will be measured – see later in this application not for a list of the parameters measured during the autotune.

The autotune must complete successfully, and the drive must go back to showing “Stop” on the display. If the drive trips during the autotune, refer to the drive user guide for information on the relevant fault and methods to resolve.

Once the autotune has completed, it should be possible to operate the motor. The following section then provides information on how to optimize the performance further.

Optimizing the Motor Operation:

Low Speed / Starting Boost

In general, it is possible to operate with PM motors with a speed range of up to 20:1. The P2 drive provides a boost function that can inject additional current into the motor at low speed to help maintain the rotor alignment, which will improve operation during starting and at low speed.

Care should be taken not to cause motor over-heating issues through sustained low speed / high current boost operation.

Two parameters are used to configure this function

P7-14 Low Frequency Torque Boost

This parameter determines the level of current boost applied. Setting 10% will increase the motor current by up to 10% in the frequency range at which this current is applied. If the setting of P7-14 is too low, the drive may trip during starting, particularly with load. If the level is too high, the drive may trip with "lt.trp" (motor thermal overload) as the motor current is too high. The setting should only be high enough to ensure reliable repeat starting. Typically a setting of 10% will provide good operation.

P7-15 Torque Boost Frequency Limit

This parameter defines the frequency up to which boost is applied, e.g. if P1-09 = 200Hz, P7-15 = 10%, torque boost is applied up to $10\% \times 200\text{Hz} = 20\text{Hz}$.

Typically, a setting of 10% will provide good performance, and this can be increased if maximum motor torque cannot be achieved at low speed.

Entering Motor / Load Inertia Ratio

Parameter P7-10 allows the inertia ratio between the motor and connected load to be entered into the P2 drive. This value can normally be left at the default value (10); however it is used by the P2 control algorithm as a feed forward term in order to provide optimum torque / current to accelerate the load. Hence accurate setting of the inertia ratio will produce better system response and dynamics. If value is unknown then leave value set to default (10).

The value entered into P7-10 is given as;

$$P7-10 = (J_{Tot} / J_{Mot}) \cdot 10$$

Where;

J_{Tot} is Total Inertia (including motor, load, and any coupling)

J_{Mot} is Motor Inertia

Motor inertia will be given by the motor manufacturer as part of their standard motor data.

Total inertia must either be known from the system design or measured.

Setting baseline values for speed loop gains

PM motor control uses a vector algorithm, and as such, the response of the speed loop can be adjusted for optimal performance. The Default gains values for the speed controller are generally suited to standard induction motor control. PM motors typically permit high gains values and faster response for improved performance. The recommended starting values for PM motor control are:

P4-03: Speed Controller proportional Gain, Set to Value 50 (%).

P4-04: Speed Controller Integral Time Constant, Set to Value 100 (ms).

These values may need to be adjusted at the end of the process when system performance can be monitored for effective tuning and improvement.

Tuning Speed Controller Responses

Changes to the speed controller tuning parameters should be made very gradually with close observation of the resulting effect on system response.

P4-03: Speed Controller proportional Gain

The proportional gain is used to change the output to the motor as a proportional of the error in the speed loop controller (difference between commanded and actual speed). The proportional response of the drive is adjusted by multiplying the error by a constant called the proportional gain that is set in parameter P4-03. Increasing the value in parameter P4-03 decreases drive response times / improves system dynamics.

If proportional gain is set too low the system response will be poor (slow) however if set too high the system could oscillate and could grow unstable.

P4-04: Speed Controller integral time constant

The integral gain is an 'accumulated' gain based on both the magnitude of the error in the speed controller and the time the error has existed, essentially working to eliminate prolonged and steady state error in the system.

Parameter P4-04 is set as a time (in ms). The smaller the time (integration time) the more responsive the drive output, at the possible expensive of instability.

Small amounts of integral gain can have a significant effect on reaction times and stability of the speed controller.

General practice with tuning a PI system is to set the integral value (P4-04) to its highest possible setting (1.0 sec) and tune the proportional value (P4-03) for optimum performance. When proportional gain has been set / optimized then the integral gain (P4-04) can then be adjusted to eliminate steady state speed errors.

Adjusting the Motor Magnetizing (Starting) time.

Parameter P7-12, Motor Magnetizing time, sets a delay time between the drive output being enabled, and the frequency being ramped to the set-point. This delay is used by the drive to establish magnetizing current in the motor windings and to align orientation of the rotor to a known position. Magnetizing current applied is defined by P7-14.

This function creates a start-up delay, however if insufficient time is provided to magnetize and orientate the rotor position then start up and operational performance could be affected, and the drive may trip during starting. If this occurs, P7-12 may be increased.

In cases where it is desirable to minimize this time, ensure that the reduced time does not create occasional motor starting problems.

Changing P2 Torque Limits

Drive torque limits (proportionally related to current limits) are adjusted by parameters P4-07 (for drive motoring torque), and P4-09 (for drive generating torque) respectively.

Generally PM motors have a significantly higher peak torque rating in relation to nominal torque (>200% of nominal torque), such that these values do not normally need to be adjusted. Peak torque values are available from the motor technical data sheet and if less than 200% of nominal torque these parameters can be adjusted to provide peak torque to the motor.

Tips & Tricks for Optimization

There are a wide variety of different PM & BLDC motor types now available, and the information provided by different manufacturers can be extremely variable. As such, it can be difficult and often time consuming to find the correct settings and resolve problems. This section provides some guidance on ensuring that parameters are set correctly.

Check P0-14 – Motor Magnetizing Current

When basic motor parameters have been entered and an autotune completed, if it is possible to start the motor, check the value shown in P0-14 during operation. PM and BLDC motors require no magnetizing current, so when operating in a speed range approx. 50 – 70% of rated speed, this parameter should be 0. A value of + / - 0.1A is acceptable, otherwise this often indicates that the Back EMF value entered in P1-07 is incorrect – adjust the value and try again.

In general, if the magnetizing current shows a positive value, P1-07 is most likely too high, whereas a negative value indicates too low a value.

PM & BLDC Motor Parameters

The following sections provide a list of the parameters which are relevant to PM & BLDC motor operation. Refer to the P2 Advanced User Guide for further information on these parameters.

Parameters Related to PM Motor Operation

Par.	Function
P1-03	Acceleration ramp time
P1-04	Deceleration ramp time
P1-07	Nominal back emf
P1-08	Motor rated current
P1-09	Motor rated frequency
P1-10	Motor rated speed
P1-14	Extended menu access
P2-24	Switching frequency
P4-01	Control Mode
P4-02	Motor parameter auto-tune
P4-03	Speed Controller proportional Gain
P4-04	Speed Controller integral time constant
P4-07	Maximum motoring Torque limit
P4-09	Maximum generating Torque limit
P7-10	Inertia Ratio
P7-12	Motor Magnetizing Time
P7-14	Boost Current Level
P7-15	Boost Frequency

Parameters Measured During The Autotune

The following parameters are measured during the autotune. They may be adjusted manually, however this is not recommended – the measured values will normally be extremely accurate, and should only be adjusted by users who understand the principles of operation and the effect of the parameter adjustment.

Par.	Description
P7-01	Motor Stator Resistance
P7-03	Motor Stator Inductance
P7-05	PM Motor LSQ

Troubleshooting

Trip codes and fault diagnostic information is provided in the standard P2 manual. Below is further troubleshooting information specific to PM & BLDC motor control.

Symptom	Solution/Advice
Cannot set P4-01 for PM motor Control	PM motor access code not entered in P1-14. Value '201' required
Delay seen after drive enable	There is an in-built delay after enable to magnetize and orientate the motor shaft immediately after enable. Delay time is controlled by parameter P7-12. See drive optimization setting for optimal setup.
Auto-tune failure	See standard P2 user guide
Poor torque Performance at low speed	Some low speed current boost required. See Low speed boost phase in set up section.
Too much current causing motor to heat up	Check parameter P1-07, motor nominal voltage is set correctly Check parameter P1-08, motor nominal current is set correctly If operating for sustained time period at low speed check levels of boost current applied (P7-14, and P7-15)
Motor Stalled	Check motor connection Check values entered into motor parameters (P1-07 to P1-10) Check Auto-tune performed Reduce the load Increase acceleration / deceleration time Increase drive / motor rating
Unstable motor speed	Check switching frequency hasn't been adjusted below recommended minimum (16 kHz) Check values entered into motor parameters (P1-07 to P1-10) Check Auto-tune performed Check appropriate tuning of speed loop controller, reduce gains as required
Poor motor dynamics, slow response times	Check values entered into motor parameters (P1-07 to P1-10) Check Auto-tune performed Check appropriate tuning of speed loop controller, increase gains as required

Revision History

Version	Comments	Author	Date
3	Corrected description of P7-12 function	KB	20170510
2	Revised & simplified	KB	20150520
1	New Application Note Created	JP	20120319

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