

PowerXL™

DM1Pro Variable Frequency Drives

Vector control setup for small motors



Level 3	<ul style="list-style-type: none">1 – Fundamental – No previous experience necessary2 – Basic – Basic knowledge recommended3 – Advanced – Reasonable knowledge required4 – Expert – Good experience recommended
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Original Application Note

Original document is the English version of this document.

Translation

All non-English language versions of this document are translations of the original application note.

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DANGER!
DANGEROUS ELECTRICAL VOLTAGE!

- Installation requires qualified electrician.
- Disconnect the power supply of the device.
- Ensure that devices cannot be accidentally restarted.
- Verify isolation from the supply.
- Cover or enclose any adjacent live components.
- Follow the engineering instructions (AWA/IL) for the device concerned.
- Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system.
- Before installation and before touching the device ensure that you are free of electrostatic charge.
- The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization. The system installer is responsible for implementing this connection.
- Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions.
- Suitable safety hardware and software measures should be implemented for the I/O interface so that an open circuit on the signal side does not result in undefined states.
- Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the specification, otherwise this may cause malfunction and/or dangerous operation.
- Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatching of the emergency-stop devices must not cause a restart.
- Devices that are designed for mounting in housings or control cabinets must only be operated and controlled after they have been properly installed and with the housing closed.
- Wherever faults may cause injury or material damage, external measures must be implemented to ensure a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, mechanical interlocks etc.).
- The used device may have hot surfaces during and immediately after operation.
- Removal of the required covers, improper installation or incorrect operation of motor or device may destroy the device and may lead to serious injury or damage.
- The applicable national safety regulations and accident prevention recommendations must be applied to all work carried on live device.
- The electrical installation must be carried out in accordance with the relevant electrical regulations (e. g. with regard to cable cross sections, fuses, PE).
- Transport, installation, commissioning and maintenance work must be carried out only by qualified personnel (IEC 60364, HD 384 and national occupational safety regulations).
- Installations containing device must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the device using the operating software are permitted.
- All covers and doors must be kept closed during operation.
- To reduce the hazards for people or equipment, the user must include in the machine design measures that restrict the consequences of a malfunction or failure of the device (increased motor speed or sudden standstill of motor). These measures include: – Other independent devices for monitoring safety related variables (speed, travel, end positions etc.).
 - Electrical or non-electrical system-wide measures (electrical or mechanical interlocks).
 - Never touch live parts or cable connections of the device after it has been disconnected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. Consider appropriate warning signs.

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1 Introduction

DM1Pro supports sensorless vector motor control mode. This motor control mode can be used for applications with standard asynchronous motors that require accurate motor speed regulation and high torque at low speed. To achieve this the VFD calculates and controls the motor's magnetic flux and torque components independently and uses an internal motor model to estimate rotor speed and position. It is required to set the correct motor parameters and perform a motor identification run for the drive, to control the motor in this mode.

	<p>Note Sensorless vector control mode requires correct motor parameter settings and performing of a Motor Identification.</p>
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Usually, these steps are sufficient to run a standard asynchronous motor in open loop vector motor control mode. DM1Pro offers certain parameters to fine tune the sensorless vector control mode. When using small parameters is very likely that fine tuning is required to ensure smooth motor control.

This Application note will explain the available parameters in DM1Pro that can be used to fine tune this motor control mode.

For PM Motors additional Parameters are used, that won't be covered in this Application Note, for more information about PM motor control see DM1 Application Note "AP040220EN - Permanent magnet synchronous motor control (PMSM) using PowerXL DM1 variable frequency drives".

2 Setting the required Parameters

The sensorless vector control mode is only available in the MultiPurpose Application. Please make sure to change the Application setting first as some Parameters will reset to default setting when changing the application. The following parameter settings are required:

Table 1: Required Parameters

Code	Parameter	required setting	Default setting	Unit	ID	Comment
P13.1.2	Application	3 = MultiPurpose	0 = Standard		142	Parameter value can only be changed after the drive has stopped. The DM1 will reset after modification
P1.1	Min Frequency	based on application requirements	0.00	Hz	101	A separate Ramp is used for 0 to Min Frequency that can be set via P9.2.6
P1.2	Max Frequency	based on application requirements	MaxFreqMFG	Hz	102	MaxFreqMFG was 100Hz for older units and now is 50Hz for EU and 60Hz for US
P1.3	Accel Time 1	based on application requirements	20.0	s	103	larger motors also require a larger ramp time.
P1.4	Decel Time 1	based on application requirements	20.0	s	104	larger motors also require a larger ramp time.
P9.2.6	Min Frequency Ramp time	based on application requirements	10.0	s	1850	only used when Min Frequency is larger than 0.
P1.6	Motor Nom Current	according to motor Nameplate	DriveNomCurrCT	A	486	DriveNomCurrCT is the rated CT current that can be read from the type label of the DM1.
P1.7	Motor Nom Speed	according to motor Nameplate	MotorNomSpeedMFG	rpm	489	MotorNomSpeedMFG is 1485rpm for EU and 1770rpm for US.
P1.8	Motor PF	according to motor Nameplate	0.85		490	
P1.9	Motor Nom Voltage	according to motor Nameplate	MotorNomVoltMFG	V	487	MotorNomVoltMFG value is depending on the nominal Voltage and Region setting of the DM1
P1.10	Motor Nom Frequency	according to motor Nameplate	MotorNomFreqMFG	Hz	488	MotorNomFreqMFG is 50Hz for EU/APAC and 60Hz for US Region
P5.1.1	Motor Control Mode	2 = Open Loop Vector Control	0 = Freq Control		287	Open Loop Vector Control is only available in MultiPurpose Application
P5.1.16	Identification	3 = Identification No Run	0 = No Action		299	After enabling this parameter a start command must be given within 30 seconds to start the Motor Identification or parameter will go back to default.

2.1 Motor Identification

If the load can be uncoupled from the motor, you can also perform a Motor Identification with run (P5.1.16 = 2).

When you are using an external Keypad (DXG-KEY-LCD) it will show “auto tune...” during Motor Identification.



After successful completion of the Motor Identification the Display will show the message “Identification successful”. The measured values can be reviewed via these Parameters:

Table 2: Parameters measured during Identification Run

Figure 1: Motor Identification

Code	Parameter	Default setting	Unit	ID	Comment
P5.1.17	Stator Resistor	0.033	ohm	771	Motor stator resistor real value, this value is the stator winding resistance of the windings in the motor.
P5.1.18	Rotor Resistor	0.034	ohm	772	Motor rotor resistor real value, this value is the rotor resistance of the motor.
P5.1.19	Leak Inductance	0.12	mh	773	Motor leakage inductance real value, this value is the amount of magnetic inductance that does not link to a winding in the motor.
P5.1.20	Mutual Inductance	3.4	mh	774	Motor mutual inductance real value, this value is the amount of inductance between 2 sets of windings in the motor.
P5.1.21	Excitation Current	0.10	A	775	Motor no-load current real value, this value is the amount of electrical current required to generate a rotating magnetic field in the motor.
P5.1.22	Motor Inertia	0.010	kgm2	1881	System rotation inertia real value for speed loop parameter tuning.

If the Motor Identification fails, make sure that no capacitors are installed in the drive output (e.g. from a dV/dt filter) and that the motor cables are not too long.

It could also fail if the DM1 is assigned a much higher motor power than the connected motor. Usually with Open Loop vector control it is recommended that the VFD is sized maximum 1-2 power sizes higher than the motor. It is also not possible to run 2 Motors in parallel on the same output in this Control Mode.

If you have a Motor Datasheet available, that lists the values for the Identification Parameters, you can use these by overwriting the parameter values from the DM1.

3 Commissioning

Before you start commissioning, please make sure that the correct control Place is active (Local via Keypad or Remote via I/O).

For commissioning the open loop vector control mode, it is recommended to use 2 separate control devices simultaneously (e.g. PC Software or External Keypad together with the onboard Keypad). In this way it is possible to change a Parameter during run and directly see the influence on the monitored parameter. If available an oscilloscope to measure the motor current can also be used to detect the correct parameter settings for the open loop vector motor control mode. The goal is to have a stable output current without much oscillation.

The DM1 should now be able to start and ramp up the motor. If this is not the case, there are a few possibilities listed here that might cause the motor not to run at all:

- No Start Signal was detected, or no speed reference was given. Check the Monitor to see if the digital input is active (M2.4) and that the speed reference is >0 (M1.2).
- DM1 is in fault state. Check that there are no active faults.
- STO or enable Signal is missing. Check STO and Input settings of the DM1. It is possible to set the STO response to “No Action” (P6.2.11) in case of open STO circuit the DM1 won’t give a fault message but won’t be possible to operate.
- DM1 is in current limitation because the output current exceeds the current limit setting (P5.1.2). Possible causes for this are:
 - Current Limit is set to the motor rated current or lower. Make sure that the current limit is set to allow a motor to start.
 - Motor is mechanically blocked. Check that the Motor is free to rotate.
 - Motor Identification measured a too high value “Excitation Current” (P5.1.21). You can try to lower the setting or try with default setting and check the influence on the Motor current).
 - Motor Identification measured a too high value “Motor Inertia” (P5.1.22). You can try to lower the setting or use the default setting and check the influence on the Motor current).
- DM1 is supplied with control Voltage only. Make sure that the mains are connected, and DC Link Voltage is available (M1.8).

4 Fine Tuning Open Loop Vector Control

DM1 offers Parameters to fine tune the open loop Vector Control Mode, the most important ones can be found in Parametergroup P5.2 “SVC Parameters”. The table below shows all Parameters that have an effect with active Motor Control Mode = 2 “Open Loop Vector Control”.

The **grey** Parameters are measured during successful identification and usually do not need to be modified by the user unless Identification failed or more accurate motor manufacturer data are available. The **bold** Parameters are typically used to fine tune the open loop vector control mode.

Table 3: Motor Control Parameters for “Open Loop Vector Control”.

Code	Parameter	Comment
P5.1.2	Current Limit	This is the maximum current allowed by the drive (130% of the rated current)
P5.1.10	Switching Frequency	Sets the switching frequency for the PWM output waveform.
P5.1.11	Sine Filter Enabled	This parameter enables the drive to have a fixed switching frequency for use with sine filters.
P5.1.12	OverVoltage Controller	The overvoltage control is used to limit the DC link voltage below the preset limit value
P5.1.13	Over Voltage Controller Reference	The over voltage reference defines the preset limit value used in the overvoltage controller.
P5.1.14	Load Drooping	The drooping function enables speed drop as a function of load.
P5.1.15	Droop Control Filter Time Constant	Filter time when using droop control
P5.1.17	Stator Resistor	Motor stator resistor is measured when performing Identification (P5.1.16).
P5.1.18	Rotor Resistor	Motor rotor resistor is measured when performing Identification (P5.1.16).
P5.1.19	Leak Inductance	Motor leakage inductance is measured when performing Identification (P5.1.16).
P5.1.20	Mutual Inductance	Motor mutual inductance is measured when performing Identification (P5.1.16).
P5.1.21	Excitation Current	Motor no-load current is measured when performing Identification (P5.1.16).
P5.1.22	Motor Inertia	System rotation inertia for speed loop parameter tuning is measured when performing Identification (P5.1.16).
P5.2.1	Speed Error Filter Time Constant	Filter time constant for speed reference and actual speed error.
P5.2.2	Speed Control Kp1	Sets P-gain of 'Vector' control mode speed controller for output frequency \leq Speed Control FS1.
P5.2.3	Speed Control Ti1	Sets time constant of 'Vector' control mode speed controller for output frequency \leq Speed Control FS1.
P5.2.4	Speed Control FS1	Sets the 'Vector' control mode frequency setpoint 1.
P5.2.5	Speed Control FS2	Sets the 'Vector' control mode frequency setpoint 2.
P5.2.6	Speed Control Kp2	Sets P-gain of 'Vector' control mode speed controller for output frequency \geq Speed Control FS2.
P5.2.7	Speed Control Ti2	Sets time constant of 'Vector' control mode speed controller for output frequency \geq Speed Control FS2.
P5.2.8	Motoring Torque Limit FWD	Motoring torque limit in the forward direction.
P5.2.9	Generator Torque Limit FWD	Torque limit in the forward direction when the motor becomes a generator.
P5.2.10	Motoring Torque Limit REV	Motoring torque limit in the reverse direction.
P5.2.11	Generator Torque Limit REV	Torque limit in the reverse direction when the motor becomes a generator.
P5.2.12	Motoring Power Limit	Motor Power limit setting.
P5.2.13	Generator Power Limit	Power limit setting when the motor becomes a generator.
P5.2.14	Flux Reference	This parameter defines the amount of flux that is output to the motor.
P5.2.19	Observer Kp	Linear gain of the PM/IM observer to estimate speed and position.

4.1 Optimizing at zero speed

When the load is decoupled and a start command is issued with the speed reference set to 0, the motor shaft should ideally not rotate. If the rotor oscillates between forward and reverse, this may be due to an excessively high excitation current. Check the setting of P5.1.22 and if it is set higher than 1/3 of the motor nominal current (P1.6) then reduce the setting to 20-30% of the motor nominal current. If the value is too low, the motor will lose torque and probably does not start turning when a speed reference is given. If the motor shaft does not turn you can couple the load and check if the motor starts turning when a speed reference >0 is set. If not, then increase the Excitation Current in P5.1.22.

4.2 Optimizing Motor Speed Controller

The Motor Speed Controller in DM1Pro is a PI Controller with 3 frequency ranges that can be set via 2 Setpoint Parameters, between those two setpoints the proportional (Kp) and integral (Ti) components are interpolated.

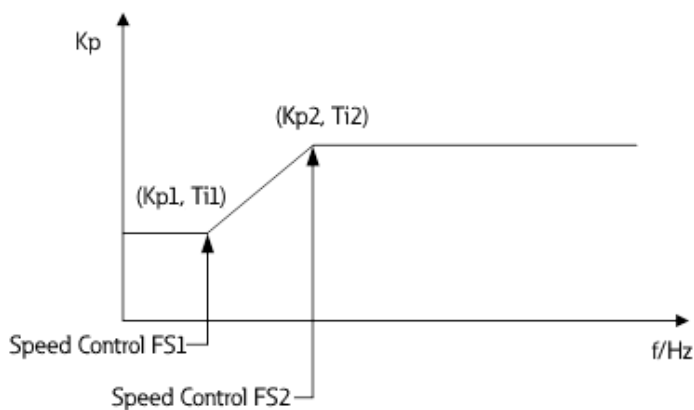


Figure 2: Speed Controller DM1Pro

Whereas bigger motors might work with just one setting for the complete speed range on smaller motors it is necessary to use both Setpoints to get a stable operation.

All Speed Controller Parameters can be changed during operation.

Use a monitoring device (PC Software or external Keypad) to monitor the output frequency (M1.1), motor speed (M1.3) and motor current (M1.4) of the DM1.

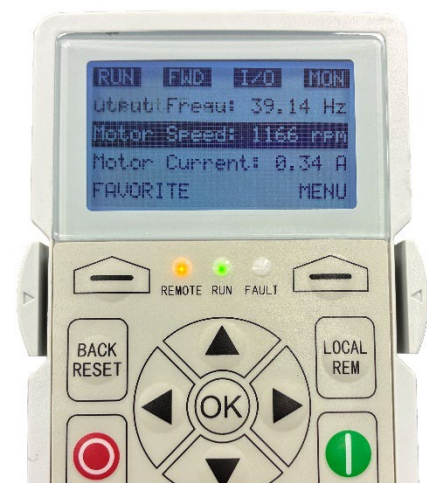


Figure 3: Multi-Monitor on DXG-KEY-LCD

Set the “Speed Error Filter Time Constant” (P5.2.1) to 10ms to have a faster response time of the motor speed controller.

Typically, a small motor requires a fast response from the Motor Speed Controller to start. To speed up the response of the Speed Controller at low speed you need to increase the Kp1 and decrease the Ti1 components. Set FS1 (P5.2.4) to 1Hz. Start with these values for the Motor Speed controller Kp1 (P5.2.2) = 200% and Ti1 (P5.2.3) = 20ms.

The second setpoint FS2 (P5.2.5) should be set to 5 Hz and Kp2 (P5.2.6) = 50%. Keep Ti2 (P5.2.7) on the same setting as Ti1 = 20ms.

It is recommended to use preset speed (Parameter group P2.3) or minimum frequency setting (P1.1) as frequency reference so that you do not have an oscillating reference coming from the analog input. Set the reference to a low value for example 1 Hz and check whether the motor starts turning and whether the output speed and current are stable. The output frequency may oscillate. Then increase the reference to test the performance in range 1–5 Hz.

If you see the output current oscillating, try to decrease the setting of Kp in 5% steps during operation. If the motor current is stable already you can try to increase the value in 5% steps until you see the current to become unstable. Then go back to the last setting where it was stable.

If you see overcurrent trips or cannot set a stable motor speed via Kp range 25–400% then increase Ti in 100ms steps up to 800ms.

4.3 Optimization for the use of a sine wave filter

If you are using a sine wave filter in the output of the DM1 you will need to optimize the observer Kp (P5.2.19) to be able to start the motor. Experience shows that this value can be decreased to 50% to achieve a significant improvement in the motor control.

After a successful test run you can optimize the value of “motor inertia” (P5.1.22) by performing an “identification run only inertia” (P5.1.16 = 4).

5 References

Documentation		
	Document No	LINK
Application Manual PowerXL DM1 series...	MN040049EN	DownloadCenter
Instruction Leaflet DM1 Pro...	PUB53675	DownloadCenter
PowerXL DM1 VFDs—OLV control and motor identification	AP040228EN	DownloadCenter
Permanent magnet synchronous motor control (PMSM) using PowerXL DM1 variable frequency drives	AP049220EN	DownloadCenter

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Eaton Industries GmbH
Hein-Moeller-Str. 7- 11
D-53115 Bonn

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