PowerXL™

DE1 Variable Speed Starters
Motor Data – Motor Protection – V/f curves – Slip Compensation

Level 2	1 – Fundamental – No previous experience necessary 2 – Basic – Basic knowledge recommended 3 – Advanced – Reasonable knowledge required 4 – Expert – Good experience recommended

Powering Business Worldwide

Contents

Danger! - Dangerous electrical voltage!

- 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.).
- Variable speed starters may have hot surfaces during and immediately after operation.
- Removal of the required covers, improper installation or incorrect operation of motor or variable speed starter 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 variable speed starters.
- 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 variable speed starters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the variable speed starters 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 variable speed starter (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 variable speed starter 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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General

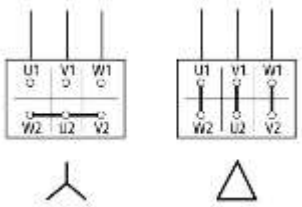
Devices of the series **PowerXL™ DE1** are Variable Speed Starters for the supply of standard asynchronous motors. By default they are configured, that motors of the respective power class can be supplied without changing the settings. Many standard cases can be covered.

There are some applications, which require an adaptation by changing parameters. In this Application Note the following aspects are covered:

- Adaptation to the connected motor
- Slip compensation
- Motor protection
- Setting the V/f curve
- Energy optimization

Motor data

Condition for a proper operation is the right connection (star / delta) of the motor to the output terminals of the device. The rated voltage of the motor windings is decisive.

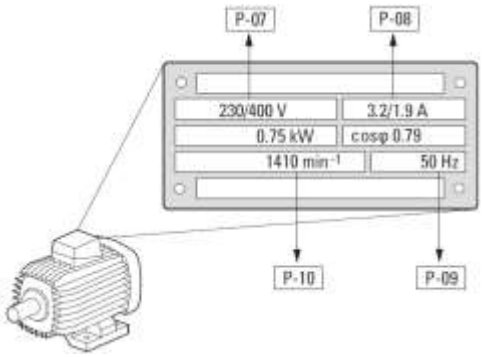


Device	Output Voltage	Motor	Connection
DE1-12…	3 x 230 V	230 / 400 V	Delta
DE1-34…	3 x 400 V	230 / 400 V 400 / 660 V	Star Delta
DE1-34…	3 x 400 V	230 / 400 V	Delta
Special case: 87 Hz-curve (see Example 4 below)			

An adaptation to the connected motor can be done with the following parameters:

- P-07 Motor Nom Voltage
- P-08 Motor Nom Current
- P-09 Motor Nom Frequency
- P-10 Motor Nom Speed

The respective values can be taken from the name plate of the motor or from the data sheet of the motor manufacturer. They are used for the setting of the motor protection and define the V/f curve.



Motor Nom Voltage (P-07)

Motor rated voltage (name plate) taking the connection (star / delta) into account. This value defines the max. output voltage of the Variable Speed Starter. Is the output frequency higher than the rated frequency of the motor (P-09), the output voltage remains on the value set with P-07. See also chapter “V/f curve” below.

Devices of the series DE1 have a voltage compensation. That means, that the output voltage is kept constant, even with fluctuation of the mains voltage. In case P-07 = 0 , the voltage compensation is disabled. In this case the maximum output voltage of the device is equal to the mains voltage at the input terminals.

In exceptional cases, a different setting of P-07 is necessary. See chapter “87 Hz curve”

PNU	Parameter	Name	Range	Default
211.0	P-07	Motor Nom Voltage	0 / 50 V … U_e	U_e

U_e = Rated voltage of the device, e.g. 230 V or 400 V, depending on device type

Motor Nom Current (P-08)

Rated current of the motor. By default, parameter P-08 „Motor Nom Current“ is set to the rated current I_e of the Variable Speed Starter. P-08 is also used to set the thermal protection for the motor. See also chapter “Motor Protection”. In case the rated current of the motor is different to the one of the Variable Speed Starter, P-08 has to be set accordingly to provide a thermal motor protection.

It must be pointed out, that this current value is set, which is assigned to the type of connection of the motor. In the example above it is 3,2 A at 230 V (Delta) respectively 1,9 A at 400 V (Star).

PNU	Parameter	Name	Range	Default
210.0	P-08	Motor Nom Current	0.1 · I_e … I_e	I_e

I_e = Rated current of the device

Motor Nom Frequency (P-09)

Rated frequency of the motor. By default this parameter is set to the mains frequency (50 Hz in Europe, 60 Hz in USA) and doesn’t need to be changed in the majority of cases.

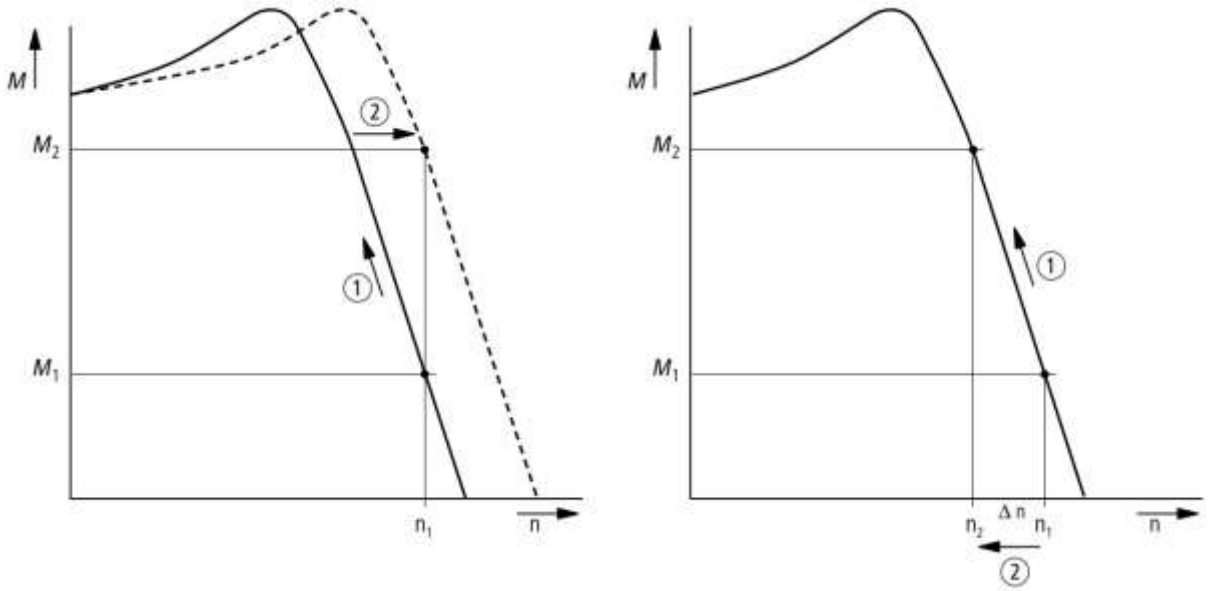
In case, motors with rated frequencies different from the mains frequency (e.g. 200 Hz for fast rotating motors) or if the 87 Hz curve is used, P-09 has to be set accordingly.

PNU	Parameter	Name	Range	Default
216.0	P-09	Motor Nom Frequency	20 … 300 Hz	50 Hz resp. 60 Hz

Motor Nom Speed (P-10) (Switching from Hz to rpm, Slip compensation)

P-10 = 0: Setting / display of the output frequency in Hz

P-10 > 0: all speed related parameters (P-01, P-02, P-20…P-23) are set and displayed in rpm. Furthermore the slip compensation is activated, which ensures, that the motor speed is kept constant even with changing loads. In case the value of P-10 corresponds to a synchronous speed (e.g. 3000 rpm for a 2 pole motor at 50 Hz), the speed is set and displayed in rpm, but the slip compensation is not activated.



With slip compensation Without slip compensation

The slip is the difference between a synchronous speed because of a rotating field and the actual speed of the motor. The name plate in the example on page 5 shows a rated speed of 1410 rpm. It is a 4 pole motor with a synchronous speed of 1500 rpm. Between no load and rated load there is a slip of 90 rpm. Running the motor with a Variable Speed Starter, one wants to prevent the speed variance by compensating the slip.

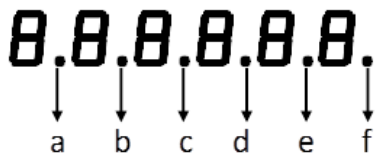
With slip compensation: at load increase ① voltage and frequency are increased accordingly ②. The speed n_1 remains constant. At load decrease voltage and frequency are reduced.

Without slip compensation: with load ① the speed drops from n_1 to n_2 ②, when unloading the speed increases again.

PNU	Parameter	Name	Range	Default
217.0	P-10	Motor Nom Speed	0 / 200 … 18000 rpm	0 rpm

Motor protection

The Variable Speed Starters of the series DE1 own an internal motor protection function, which trips the drive after a certain time in case of overload. The display shows the fault message "I.t-trP". The overload is related to the rated current of the motor, set with P-08.

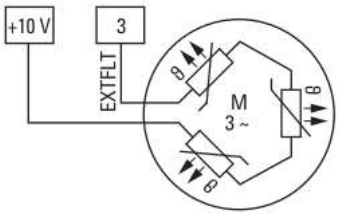


In case the output current of the device exceeds the value set with P-08 „Motor Nom Current", this status is displayed on the keypad.

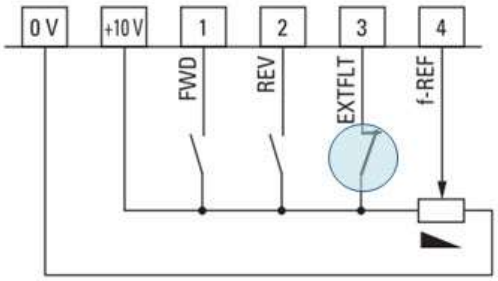
7-Segment LED display:	dots a…f are flashing
OLED display:	text „O-L" is displayed

It has to be considered that, similar to a thermal overload relay, the current is used to estimate the temperature inside the motor. This kind of "indirect temperature measurement" is sufficient in many cases, but doesn't reflect the real temperature conditions inside the motor. In case of Variable speed it has to be taken into account, that the cooling of the motor is done by an impeller, which is mounted on the motor's shaft. Therefore the cooling is reduced at lower speeds. Experience shows that this is not critical between approx. 40 % and 100 % speed, but below 40 % it can lead to problems, if the application requires full torque also in this range (= full amount of losses). In pump and fan applications where the torque is square with the speed, this effect is uncritical.

In case of steady operation with nearly rated load below 40 % rated speed it is recommended to use motors with temperature sensors (thermistors or thermo contacts), which provide information about the real motor temperature. Thermistors as well as temperature contacts can be directly connected to DE1 devices.



Example thermistor



Example temperature contact

Parameter P-15 has to be set in a way, that the function „External Fault" (EXTFLT) is assigned to terminal 3 (DI3). During proper operation, a High-Signal is applied to terminal 3. In case of fault the temperature contact must open respectively the resistance of the thermistor has to increase. DE1 trips at a resistance of $\geq$ 3.6 kΩ, Reset can be performed at values $\leq$ 1.6 kΩ.

ATTENTION: Variable Speed Starters of the series DE1 are designed according IEC / EN 61800-5-1, which requires double isolation between mains circuits and circuits with low voltage. Inside the drive power part and control part are separated accordingly. In case temperature sensors inside the motor are connected to DE1, the sensors have to be double isolated against the motor windings, not to weaken the overall insulation system!

When several motors are connected in parallel at the output of the Variable Speed Starter, each motor has to have a separate (external) protective device.

SwitchRemanentStorage (P-33)

Variable Speed Starters calculate the thermal image of the motor based on the current. In case the function "SwitchRemanentStorage" (P-33) is ON, the calculated value is stored automatically on power down. The stored value is used on next power up. If this function is disabled, the motor thermal history is reset to zero.

Hint: The thermal memory is also active when the Variable Speed Starter is powered up, but no START command active. This takes into account a cooling of the motor during this phase.

PNU	Parameter	Name	Range	Default
682.0	P-33	SwitchRemanentStorage	0 = ON 1 = OFF	0 = ON

If variable Speed Starters DE1 are used under the scope of UL, the remanent storage has to be active (P-33 = 0).

V/f curve

The V/f curve determines the magnetizing of the motor. In the simplest case the V/f curve is linear (default). This means that we have rated voltage at rated frequency and e.g. half of the rated voltage at half of the rated frequency. This is sufficient in many cases. But there are also situations where the V/f curve has to be adopted according to the requirements of the application, mostly in those cases where the max speed is above rated speed or where high torque is required, even in the lower speed range.

The following parameters influence the V/f curve

- P-01 f-max
- P-06 EnergyOptimizer
- P-07 Motor Nom Voltage
- P-09 Motor Nom Frequency
- P-11 V-Boost

f-max (P-01)

Determines the maximum output frequency of the device. Normally this corresponds with the motor rated frequency set with P-09. In case P-01 is higher than P-09, the voltage is kept constant in the range above P-07.

PNU	Parameter	Name	Range	Default
20.1	P-01	f-max	f-min … 5 · P-09	50 Hz resp. 60 Hz

Energy Optimizer (P-06)

The function „Energy Optimizer“ enables an automatic adaptation of the output voltage to the load conditions. Objective is, to reduce losses inside the Variable Speed Starter as well as in the motor by reducing the output voltage.

PNU	Parameter	Name	Range	Default
626.1	P-06	EnergyOptimizer	0 = OFF 1 = ON	0 = OFF

Motor Nom Voltage (P-07)

This value defines the maximum output voltage of the Variable Speed Starter. In the frequency range above P-09, the output voltage remains at the value set with P-07.

PNU	Parameter	Name	Range	Default
211.0	P-07	Motor Nom Voltage	0 / 50 V … U_e	U_e

U_e = Rated voltage of the device, e.g. 230 V or 400 V, depending on device type

Motor Nom Frequency (P-09)

This value defines the frequency at which the maximum output voltage is reached (cut-off frequency).

PNU	Parameter	Name	Range	Default
216.0	P-09	Motor Nom Frequency	20 … 300 Hz	50 Hz resp. 60 Hz

V-Boost (P-11)

Voltage boost in the lower frequency range to compensate the internal voltage drop of the motor. This causes a better torque behavior in the lower frequency range. Too high values can lead to an increased temperature inside the motor.

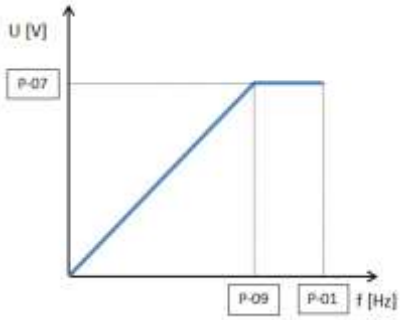
PNU	Parameter	Name	Range	Default
27.0	P-11	V-Boost	0 … 40 % Ue	3.0 %*

* 3.5 % at DE1…-129D6…

Examples

Example 1: Linear V/f curve

The output voltage increases linear with the frequency from 0 up to the value set with P-07, which is reached at the frequency set with P-09. In the frequency range above P-09 the voltage remains constant. In the majority of cases the maximum frequency (P-01) corresponds to the rated frequency of the motor (P-09).

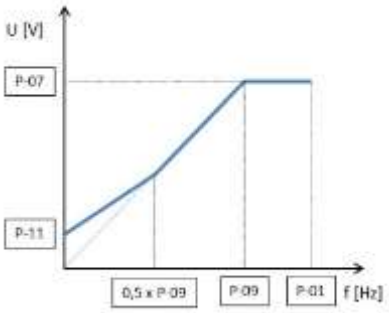


Parameters:

- P-01 = max. required frequency
- P-06 = 0 (Energy Optimization OFF)
- P-07 = max. voltage (mostly mains voltage)
- P-09 = rated frequency of the connected motor
- P-11 = 0 %

Example 2: Linear V/f curve with voltage boost

Because of the internal voltage drop of the motor there is a poor torque behavior in the low frequency range when the V/f curve is just linear. The torque behavior can be improved by increasing the voltage in the lower range. This is done with the parameter V-Boost (P-11).



The voltage starts at the value set with P-11 and increases linearly until it reaches the linear curve, defined by P-07 and P-09, at half of P-09.

Parameters:

- P-01 = max. required frequency
- P-06 = 0 (Energy Optimization OFF)
- P-07 = max. voltage (mostly mains voltage)
- P-09 = rated frequency of the connected motor
- P-11 = x % (according to the torque requirements. Too high values have to be prevented because of the increased losses inside the motor.)

Example 3: Energy Optimization (automatic modification of the V/f curve)

In the previous examples there was a fixed voltage assigned to each frequency. There are also applications with different torque demands, also at the same speed / frequency. With a fixed V/f curve the max. torque has to be taken into account without the possibility to reduce losses.

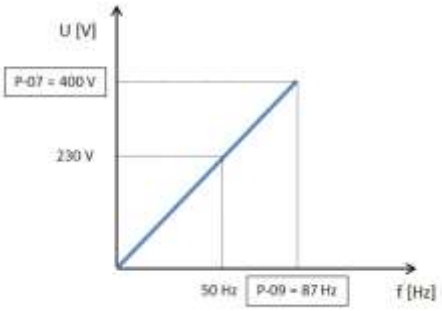
In case the Energy Optimization is active (P-06 = 1) the Variable Speed Starter detects a part load automatically and reduces the voltage accordingly. When the load increases again, voltage is also increased. To prevent oscillations inside the system the voltage variation is not done suddenly, but over time. Therefore this function is not suitable for application with cyclic load changes.

Parameters:

- P-01 = required max. frequency
- P-06 = 1 (Energy Optimization ON)
- P-07 = max. voltage (mostly mains voltage)
- P-09 = rated frequency of the connected motor
- P-11 = 0 %

Example 4: 87 Hz – Curve

In the majority of cases standard asynchronous motors are used up to their rated frequency. The maximum output frequency of the Variable Speed Starter is 50 Hz. The power of the motor can be increased by √3, by increasing the frequency from 50 Hz to 87 Hz (50 Hz · √3), keeping the flux (magnetizing current) constant at the same time.



Conditions at a 400 V mains

- The motor is wounded for 230 / 400 V (not 400 / 690 V)
- The windings are connected in delta.
- The Variable Speed Starter has a maximum output voltage of 400 V and a maximum frequency of 87 Hz. This results in 50 Hz at 230 V.
- The Variable Speed Starter is selected for a current which is the rated current of the motor at 230 V.

Parameters

- P-07 = 400 V
- P-09 = 87 Hz (with 50 Hz on the name plate)

ATTENTION: When using a 50 Hz motor at 87 Hz, possible imbalances of the rotor can cause mechanical damages. It is recommended to contact the motor manufacturer before using this motor at speeds above rated speed.

Example for selection:

Motor data

- 230 / 400 V
- 3,2 / 1,9 A
- 0, 75 kW
- 1410 min^{-1}
- 50 Hz

Selection

- Device rated for 400 V, but for the current which is assigned to 230 V (here: 3,2 A) → DE1-343D6FN-N20N.
- The power of the motor results in 0,75 kW · √3 = 1,3 kW (rated torque at √3 times rated speed).
- The synchronous speed of the motor is 1500 rpm · √3 = 2598 rpm
- The expected speed at rated load is 2598 rpm – 90 rpm = 2508 rpm
  Remark: 90 rpm corresponds to the slip speed (1500 min^{-1} – 1410 min^{-1})