PowerXL™

DA1 + DC1 Variable Frequency Drives and DE1 Variable Speed Starters
How does the internal motor protection work?

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.).
- Frequency inverters may have hot surfaces during and immediately after operation.
- Removal of the required covers, improper installation or incorrect operation of motor or frequency inverter 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 frequency inverters.
- 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 frequency inverters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the frequency inverters 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 frequency inverter (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 frequency inverter 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.

Disclaimer

The information, recommendations, descriptions, and safety notations in this document are based on Eaton's experience and judgment and may not cover all contingencies. If further information is required, an Eaton sales office should be consulted. Sale of the product shown in this literature is subject to the terms and conditions outlined in the applicable Terms and Conditions for Sale of Eaton or other contractual agreement between Eaton and the purchaser. THERE ARE NO UNDERSTANDINGS, AGREEMENTS, WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING WARRANTIES OF FITNESS FOR A PARTICULAR PURPOSE OR MERCHANTABILITY, OTHER THAN THOSE SPECIFICALLY SET OUT IN ANY EXISTING CONTRACT BETWEEN THE PARTIES. ANY SUCH CONTRACT STATES THE ENTIRE OBLIGATION OF EATON. THE CONTENTS OF THIS DOCUMENT SHALL NOT BECOME PART OF OR MODIFY ANY CONTRACT BETWEEN THE PARTIES. As far as applicable mandatory law allows so, in no event will Eaton be responsible to the purchaser or user in contract, in tort (including negligence), strict liability, or otherwise for any special, indirect, incidental, or consequential damage or loss whatsoever, including but not limited to damage or loss of use of equipment, plant or power system, cost of capital, loss of power, additional expenses in the use of existing power facilities, or claims against the purchaser or user by its customers resulting from the use of the information, recommendations, and descriptions contained herein. The information contained in this manual is subject to change without notice.

General

The devices of the series DA1, DC1 and DE1 have an internal protective function, which protects the connected motor against overload. In addition it has to be prevented, that too high currents can damage the semiconductors.

This Application Note describes

- How the motor protection works
- The dependency between current and tripping time
- The determination of the recovery time after an overload

How does the motor protection work?

The way how the motor protection works can be compared with an accumulator with a maximum content of 3000 counts. Once this value is reached, the unit trips because of “Overload”.

		DA1	DC1	DE1
C_{max}	maximum number of counts	3000 [% · s]	3000 [% · s]	3000 [% · s]
r_c	count rate at cooling down (underload)	1	1	1
r_{100}	count rate > 100 % … < 150 % load	1	1	1
r_{150}	count rate > 150 % … I_{max}	16	16	16
r_{slow}	count rate < 10 Hz output frequency[1)]	1	8	1
I_{max}	maximum value of the current[2)]	200% P1-08	175% P-08	200% P-08[3)]
t_{max}	maximum time @ I_{max}	1.875 s	3.75 s	1.875 s
	SW-overcurrent trip[4)]	~205 % I_e	~177 % I_e	~177 % I_e
	HW-overcurrent trip[4)]	~210 % I_e	~180 % I_e	~180 % I_e

1) The more sensitive reaction in the lower frequency range takes into account, that the cooling of the motor is worse because of the reduced fan power.

2) Basis is the value set with parameter “Motor Nom Current”.

3) The maximum value is determined by SW and HW-overcurrent trip. With the Variable Speed Starter DE1, 200 % can only be achieved in case the value of P-08 does not exceed 88 % I_e.

4) The HW and SW-overcurrent trip depend on the rated current I_e of the device. These functions protect the device itself and are not depending on the parameter “Motor Nom Current”.

The content of the accumulator is calculated as follows:

$$C = r \cdot t \cdot OL - t \cdot UL$$

The content cannot become negative. The factor “r“ is depending on the amount of overload. Above 100 % of the value set with “Motor Nom Current” the accumulator counts up, in the range below 100 % it counts down. OL is the overload and UL the underload in percent.

Example:	120 % „Motor Nom Current“	→	OL = 20 %
	150 % „Motor Nom Current“	→	OL = 50 %
	80 % „Motor Nom Current“	→	UL = -20 %
	0 % „Motor Nom Current“	→	UL = -100 % (Device supplied)

In case the function “SwitchRemanentStorage” 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 frequency drive is powered up, but no START command active. This takes into account a cooling of the motor during this phase.

Dependency between current and tripping time

The tripping time is calculated as follows:

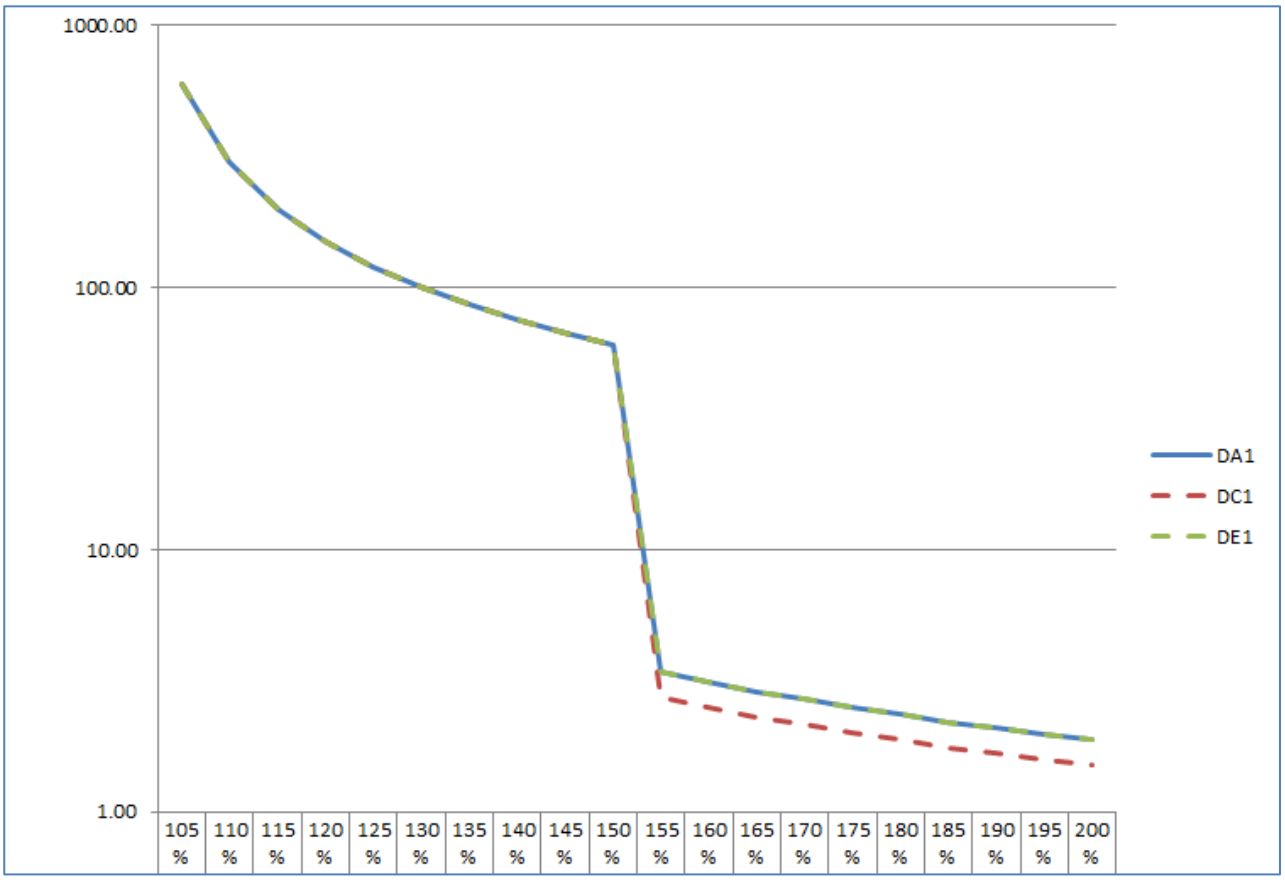
$$t = \frac{3000\ [\%\ \cdot s]}{r\ \cdot OL}$$

Example for 150 % „Motor Nom Current“ (OL = 50 % overload):

$$t = \frac{3000\ \%\ \cdot s}{1\ \cdot 50\ \%} = 60\ s$$

ATTENTION: it has to be taken into account that the count rate changes in the range above 150 %! This results in much reduced tripping times.

The diagram below shows the tripping time in seconds (vertical axis) depending on the load. The basis for the load on the horizontal axis is the parameter “Motor Nom Current”. One can easily see the impact of the count rate r_{150} above 150 %.



Tripping times

Load	Tripping time [s]	Tripping time [s]	Tripping time [s]
	DA1	DC1	DE1
100%	infinite	infinite	infinite
105%	600.00	600.00	600.00
110%	300.00	300.00	300.00
115%	200.00	200.00	200.00
120%	150.00	150.00	150.00
125%	120.00	120.00	120.00
130%	100.00	100.00	100.00
135%	85.71	85.71	85.71
140%	75.00	75.00	75.00
145%	66.67	66.67	66.67
150%	60.00	60.00	60.00
155%	3.41	2.73	3.41
160%	3.13	2.50	3.13
165%	2.88	2.31	2.88
170%	2.68	2.14	2.68
175%	2.50	2.00	2.50
180%	2.34		2.34
185%	2.21		2.21
190%	2.08		2.08
195%	1.97		1.97
200%	1.88		1.88

Determination of the recovery time after an overload

To reduce the content of the accumulator (= cooling of the motor), an operation below 100 % „Motor Nom Current“ (P-08 respectively P1-08) is necessary.

$$t = \frac{C}{UL}$$

C is the actual content of the accumulator and UL the amount of underload. t is the time until the content of the accumulator is at zero. Examples see below.

Hint: the content of the accumulator cannot be negative.

Examples

Example 1: Recovery time after a trip.

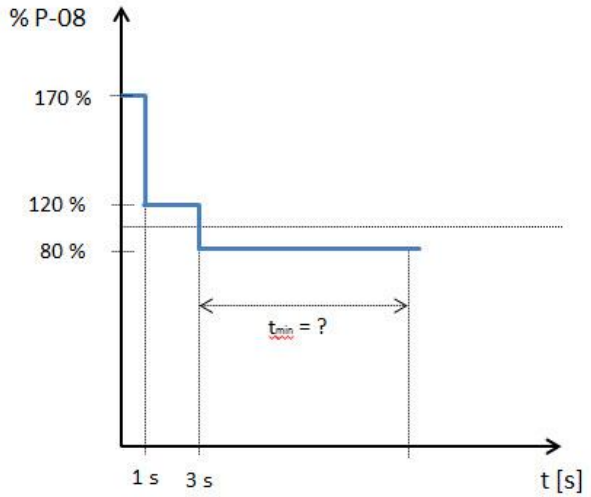
- At a trip the content of the accumulator is 3000.
- The fault can only be acknowledged when the content of the accumulator is at zero.
- During this phase, no current flows, the underload is 100 %.

$$t = \frac{C}{UL} = \frac{3000\ \% \cdot s}{100\ \%} = 30\ s$$

The recovery time after a trip is 30 s.

Hint: The supply voltage of the device has to be applied. If the device is switched off, the content of the accumulator will not be reduced (see function “SwitchRemanentStorage”

Example 2: How long is the recovery time?



A device of the series DE1 is operated with the following duty cycle:

- 1 s at 170 % „Motor Nom Current“ (P-08) (= 70 % Overload)
- 2 s at 120 % (= 20 % Overload)
- After this permanently at 80 % (100 % - 80% = 20 % Underload)
- Questions:
    1. Is it allowed to operate the device at 170 % „Motor Nom Current“ for 1 s?
    2. What is the minimum time t_{min}, until the content of overload accumulator is reduced back to zero?
    3. What is the minimum time t_{min} when the device is operated at 90 % „Motor Nom Current“ instead of 80 %? (= 10 % underload)

1. YES. According the table on page 6 the device can be operated at 200 % for 1.875 s.

2. The formula on page 6 is used. Please note that the count rate above 150 % P-08 is higher than below. During recovery always the normal rate applies.

$$r_{150} \cdot t_{150} \cdot OL_{150} + r_{100} \cdot t_{100} \cdot OL_{100} = t \cdot UL$$

$$\frac{16 \cdot 1\,s \cdot 70 + 1 \cdot 2\,s \cdot 20}{20} = 58\,s$$

3. The time is doubled to 116 s, because the denominator of the fraction is 10 instead of 20.

Example 3: Is my load cycle OK?

To ensure a reliable operation, the cycle has to be balanced. Means: taking the count rates into account, the overload may not be higher than the underload. If for example “50” remains inside the accumulator at the end of a cycle, it only takes 3000 / 50 cycles (= 60 cycles) until the device trips because of overload.