1 Temperature Derating Guide

1.1.1 Abstract

This paper provides detailed data regarding the operation of the VLT HVAC Drive FC102 at varying ambient temperature and load. There is given application specific guidelines, and the influence on the switching frequency is documented.

1.1.2 Introduction

This paper provides detailed information regarding the operation of the VLT HVAC Drive FC102 at different ambient temperature and load conditions. Application specific guidelines are given and the influence of the switching frequency is detailed.

VLT HVAC Drive FC102 General Specifications
The VLT HVAC Drive FC102 has a specified continuous output current to be able to supply a wide range of motors with different efficiencies. Full continuous rated output current can be supplied in ambient temperatures up to 45°C. With a typical full load current of EFF2 motors (see *Motor Efficiency*), full output shaft power can be maintained with the VLT HVAC Drive FC102 operating in ambient temperatures up to 50°C.

Frequency Converter Selection and Derating
The sizing of the frequency converter is generally dependant on a number of factors including:

- Motor efficiency and full load current
- Ambient temperature
- Mains supply voltage
- Motor cable length and type (e.g. screened or unscreened)
- Number of options installed (impacts the internal temperature within the frequency converter)
- Switching frequency and/or switching pattern (impacts the heat generation within the frequency converter)

Motor Efficiency
EFF classification of motors is predominantly relevant in European Union countries although it is also adopted or being considered to be adopted in other countries. It is applicable to specific motor types (e.g. totally enclosed fan ventilated, three phase AC squirrel cage induction motors in the range 1.1 to 90kW, having 2 or 4 poles, rated for 400V, 50Hz, S1 duty class).

Other motor efficiency classifications or Minimum Efficiency Performance Standards (MEPS) exist elsewhere in the world. For example in North America NEMA MG1 defines motor efficiency levels for “energy efficient” and “premium efficiency” motors for a wider range of motors than those under the EFF classification (e.g. 1 to 500HP, 2, 4 and 6 pole) and in Australia and New Zealand AS/NZS 1359.5-2004, applicable to three phase, 2, 4, 6 and 8 pole motors from 0.73kW to <185kW, defines minimum efficiency levels approximately equivalent to those of the European EFF1 level and high efficiency motors as having an even higher efficiency. Some of these efficiency requirements are voluntary and others are legally enforceable.

The efficiency of a motor is one factor that affects the full load current rating of a motor and therefore has an impact on the ambient temperature rating of the frequency converter for use with that motor when operating at full load. For example the frequency converter may be rated for operation in an ambient temperature of say 50 °C when operating at full load current of a 15kW EFF2 motor but it may be rated for operation in say 54 °C when operating at full load current of a 15kW high efficient motor according to AS/NZS 1359.5-2004 or rated for operation in say 52 °C when operating at full load current of a 20HP premium efficiency motor according to NEMA MG1.

Ambient Temperature
If the maximum ambient temperature in which the frequency converter will be installed is equal to or below the limit defined for full continuous FC output current in the *Specifications section* of the *Operating Instructions* or the *General Specifications and Troubleshooting section* of the *Design Guide* and if the factory default switching frequency will be used, there is no need to consider derating of the output current.

However if the maximum ambient temperature is higher than that defined, this guide should be used to ensure the derated continuous output current of the frequency converter at this higher maximum ambient temperature is higher than the full load current of the motor or at least higher than the maximum running current of the motor for the application.

Mains supply voltage
The mains supply voltage has a minimal affect for low powers and therefore the ambient temperature rating, current rating and derating curves are shown for the worst case situation (i.e. highest mains voltage). For higher powers (enclosure size D and above), different derating curves dependant on the mains supply voltage are shown.

Motor cable length and type
The motor cable length and type has an affect because due to the high switching frequency of the frequency converter it not only has to supply the full load current of the motor but also “charging” currents in the motor cable. The longer the motor cable or if the cable is screened instead of unscreened, the higher these charging currents. The motor cable length and type has more affect at low powers and much less at higher powers. For all powers the ambient temperature, current rating and derating curves are given for the worst case situation (150m screened/ 300m unscreened motor cable).

Number of options installed
The frequency converter can have up to three options installed (Option A (BMS high level interface communication options), Option B (I/O extension options) and Option C (application options)). The number of options installed can affect the internal temperature of the frequency converter (depending on enclosure size). Therefore for some enclosure sizes different derating curves are shown depending on the number of options installed.

Switching frequency, switching pattern and automatic adaptation
The frequency converter can be programmed to use a different switching pattern (60 AVM or SFAVM (parameter 14-00)) or switching frequency (1kHz to 16kHz (depending on size) (parameter 14-01)).

For most applications the default settings (60 AVM and 4kHz (depending on size)) will be adequate because the frequency converter automatically adapts these to ensure performance if necessary.

The frequency converter constantly checks for critical levels of internal temperature, load current, high voltage on the intermediate circuit and low motor speeds. As a response to a critical level, the frequency converter can adjust the switching frequency and/or change the switching pattern in order to ensure the performance of the frequency converter. The capability to automatically reduce the output current (i.e. automatically derate the output current) extends the acceptable operating conditions even further. This automatic adaptation function ensures continued operation of the fan, pump or compressor even in extreme operating conditions. It also helps to minimize the acoustic noise from the motor resulting from the frequency converter when operating at low speeds, which is the most critical area of operation for acoustic noise because at low speeds the acoustic noise from the motor and fan themselves is low.

The graphs that follow provide information about the mutual influence on load, ambient temperature, switching frequency, and switching pattern.

1.1.3 Motor Acoustic Noise Optimization

Additional acoustic noise from a motor when using a frequency converter can be a concern on some applications. On pump or compressor applications it is typically not a concern but on fan applications it may be. Typically it is a concern when the fan is operating at mid to low speeds. At high speeds any additional noise as a result of the frequency converter, is drowned out by the noise from the motor and fan themselves but at mid to low speeds it may be noticeable.

Changing the switching frequency to a higher value can help to reduce acoustic noise from the motor and is the most common solution to this.

Changing the switching pattern from the default setting is not often done. However, the acoustic noise from a motor will typically be less when using SFAVM than 60 AVM for the same switching frequency, although the internal frequency converter losses will be higher. The automatic adaptation function described above sets the switching pattern to SFAVM when operating at low output frequencies (approximately <30% nominal motor frequency) to help minimize acoustic motor noise. It also sets the switching pattern to 60 AVM when operating at high output frequencies (approximately >80% of nominal motor frequency) to help minimize internal losses when the frequency converter load is at its highest (particularly applicable to fans, centrifugal pumps and centrifugal chiller compressors.) To minimize acoustic motor noise in the operating range between approximately 30% and 80% motor nominal frequency a combination of changing the switching pattern and/or switching frequency can give the best results.

However, if the switching frequency is increased and depending on the application, if the switching pattern is changed from default, this can result in increased full load losses in the frequency converter and therefore the continuous current rating of the frequency converter should be derated in accordance with the graphs that follow.

1.1.4 Application Dependant Derating

Fans, centrifugal pumps and centrifugal chiller compressors
Due to the nature of these loads the maximum load (i.e. output current) occurs at nominal/maximum output frequency. The automatic adaptation function described above, ensures that when the frequency converter is operating at its highest load and therefore when its internal losses are greatest, it is operating with 60 AVM switching pattern irrespective of what the switching pattern (parameter 14-00) is programmed to. Therefore for these applications it is only necessary to refer to the graphs that follow in illustration 1.1 - 1.9 even if the switching pattern parameter is changed from default to minimize motor audible noise at mid to low output frequencies.

Screw, scroll and reciprocating compressors
Due to the nature of these loads the maximum load (i.e. output current) could occur at all output frequencies (e.g. the torque and current required to operate a screw compressor at 60% speed will typically be similar to that at 100% speed.) Therefore for these applications it is necessary to refer to either the graphs in illustration 1.1 - 1.9 (60 AVM) OR the graphs in illustration 1.10 - 1-18 (SFAVM), depending on the switching pattern programmed (parameter 14-00.) Typically this parameter will not be changed from default, so only the graphs in illustration 1.1 - 1.9 need be used, but additional graphs are shown in illustration 1.10 - 1-18 for SFAVM switching pattern for completeness. (SFAVM results in higher internal losses than 60 AVM and therefore the derating factors are different.)

1.1.5 How to Find the Derating Factor

1. Determine the application.
   - 1a If it is a fan, centrifugal pump or centrifugal compressor use steps 2 to 4 to determine which graph applies from illustration 1.1 - 1.9.
   - 1b If it is a screw, scroll or reciprocating compressor and the switching pattern (parameter 14-00) is not changed from default (60 AVM), use steps 2 to 4 to determine which graph applies from illustration 1.1 - 1.9.
   - 1c If it is a screw, scroll or reciprocating compressor and the switching pattern (parameter 14-00) has been changed from default to SFAVM, use steps 2 to 4 to determine which graph applies from illustration 1.10 - 1-18.
2. Find the enclosure type from the tables below, e.g. a 7.5 kW with mains supply 3 x 380 – 480 V and IP 55 rating is enclosure type A5.
3. If the drive is enclosure type D or E then take note of the supply voltage for the drive.
4. Find the relevant derating curve based on the information found above: application and switching pattern, enclosure type and supply voltage (if relevant).

1.1.6 Enclosure Types

3 x 200 – 240 Volt

	1,1-2,2 kW	3-3,7 kW 5	5-11 kW	15 kW	18,5 kW	22-30 kW	37-45 kW
IP 20 / chassis	A2	A3	B3	B4	B4	C3	C4
IP 21 / NEMA 1	A2	A3	B1	B2	C1	C1	C2
IP 55 / NEMA 12	A5	A5	B1	B2	C1	C1	C2
IP 66 / NEMA 12	A5	A5	B1	B2	C1	C1	C2

3 x 380 - 480 Volt

	1,1-4 kW	5,5-7,5 kW	11-18, 5 kW	22-37 kW	45-55 kW	75-90 kW	110-13 2 kW	160-25 0 kW	315-45 0 kW
IP 00	-	-	-	-	-	-	D3	D4	E2
IP 20 / chassis	A2	A3	B3	B4	C3	C4	-	-	-
IP 21 / NEMA	-	-	B1	B2	C1	C2	D1	D2	E1
IP 54-55 / NEMA 12	A5	A5	B1	B2	C1	C2	D1	D2	E1
IP 66 / NEMA 12	A5	A5	B1	B2	C1	C2	-	-	-

3 x 525 - 600 Volt

	1,1-4 kW	5,5-7,5 kW	11-18, 5 kW	22-37 kW	45-55 kW	75-90 kW	110-13 2 kW	160-31 5 kW	355-56 0 kW
IP 00	-	-	-	-	-	-	D3	D4	E2
IP 20 / chassis	A2	A3	B3	B4	C3	C4	-	-	-
IP 21 / NEMA 1	A2	A3	B1	B2	C1	C2	D1	D2	E1
IP 54-55 / NEMA 12	A5	A5	B1	B2	C1	C2	D1	D2	E1
IP 66 / NEMA 12	A5	A5	B1	B2	C1	C2	-	-	-

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1.2 Application Dependant Derating Curves

1.2.1 Typical HVAC Applications

The curves that follow in this section are applicable for the following applications:

- Fans, Centrifugal Pumps and Centrifugal Compressors
- Screw, Scroll and Reciprocating Compressors where the switching pattern is not changed from default (i.e. parameter 14-00 remains at 60 AVM).

A Enclosures

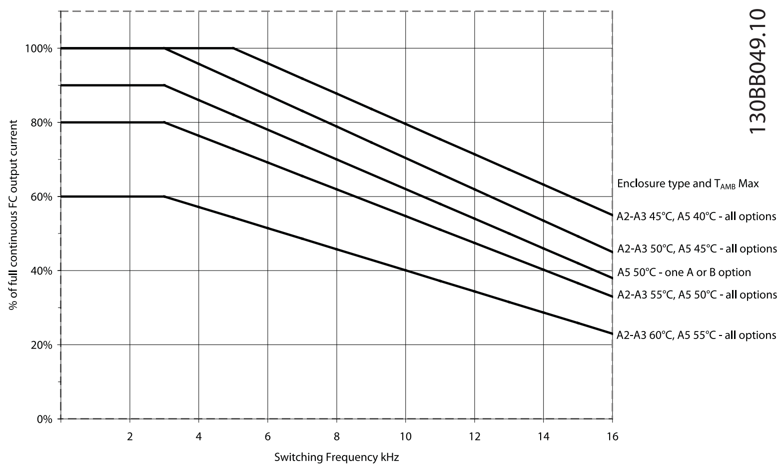

Illustration 1.1: A Enclosure Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

B1 Enclosures

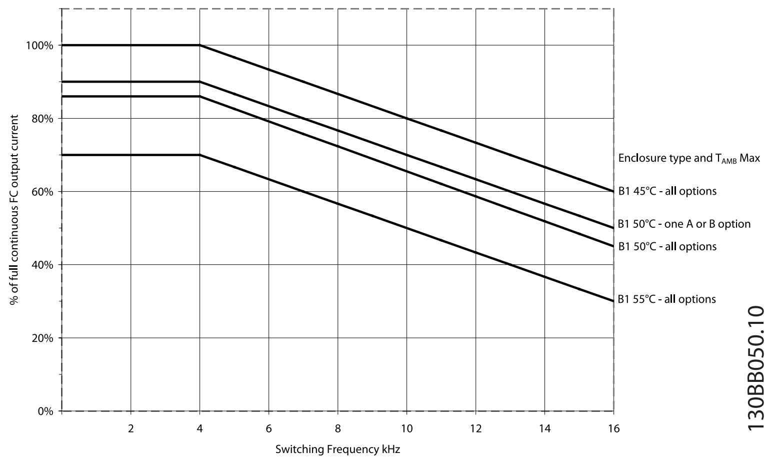

Illustration 1.2: B1 Enclosure Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

B2 Enclosures

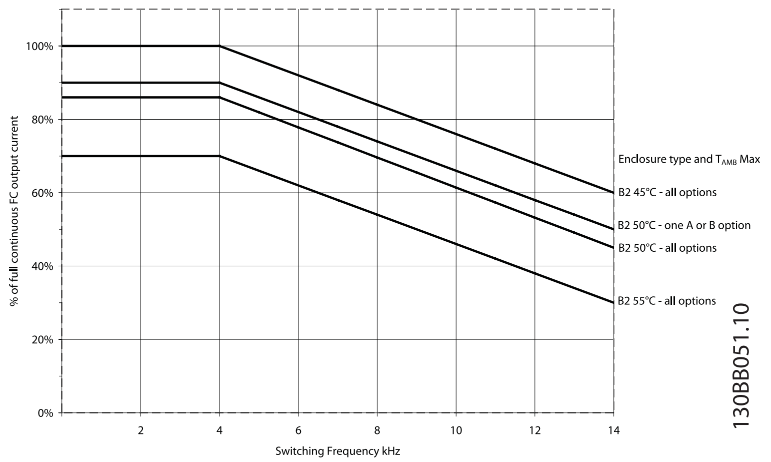

Illustration 1.3: B2 Enclosure Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

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C Enclosures

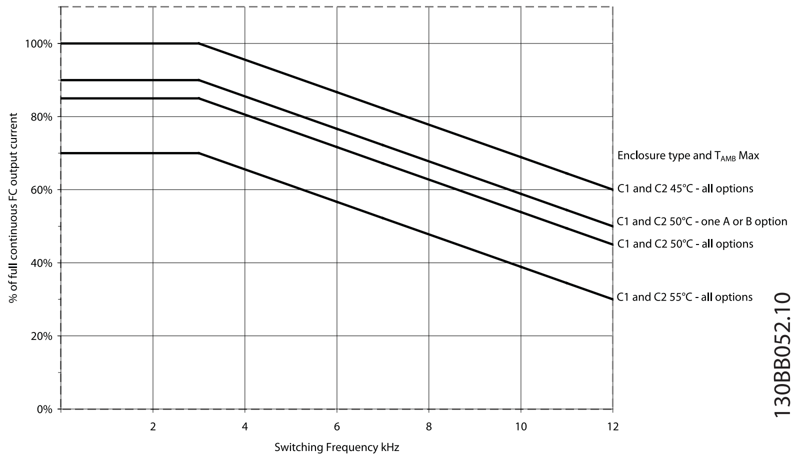

Illustration 1.4: C Enclosure Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

D Enclosures 380-480V

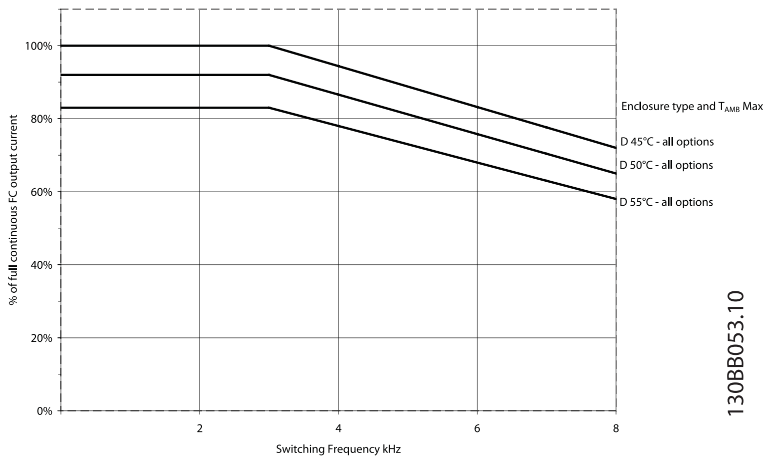

Illustration 1.5: D Enclosures 380-480V Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

D Enclosures 525-600V excluding 315kW

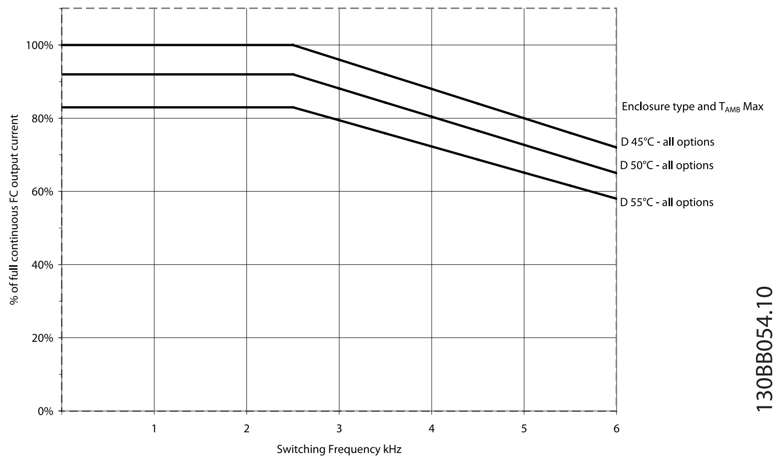

Illustration 1.6: D Enclosures 525-600V excluding 315kW Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

D Enclosure 525-600V 315kW

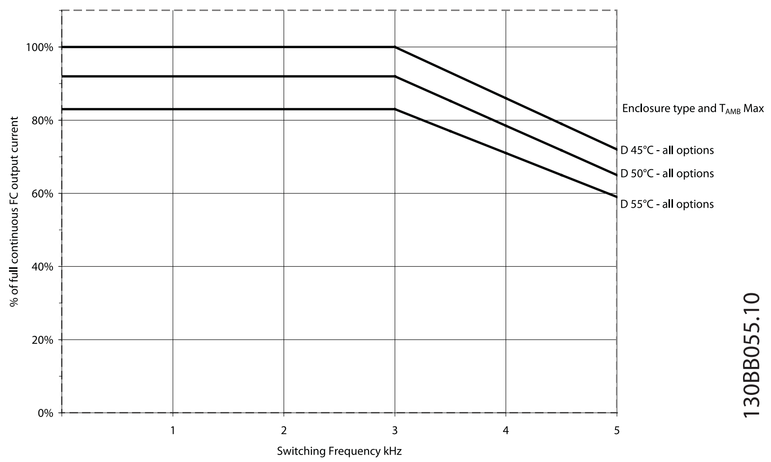

Illustration 1.7: D Enclosure 525-600V 315kW Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

E Enclosures 380-480V

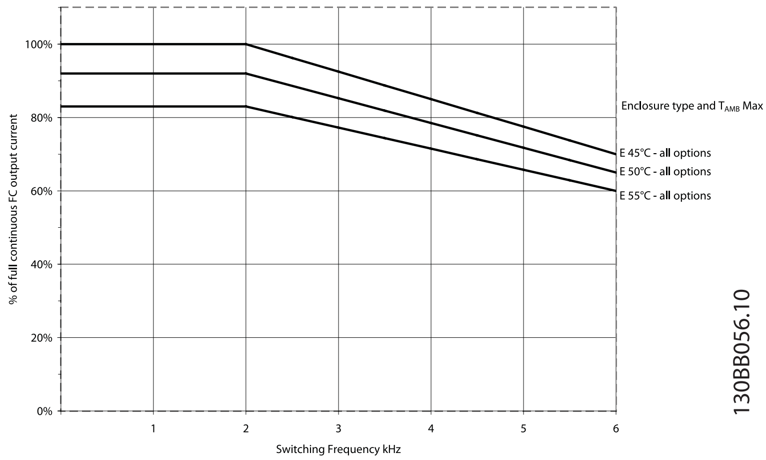

Illustration 1.8: E Enclosures 380-480V Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

E Enclosures 525-600V

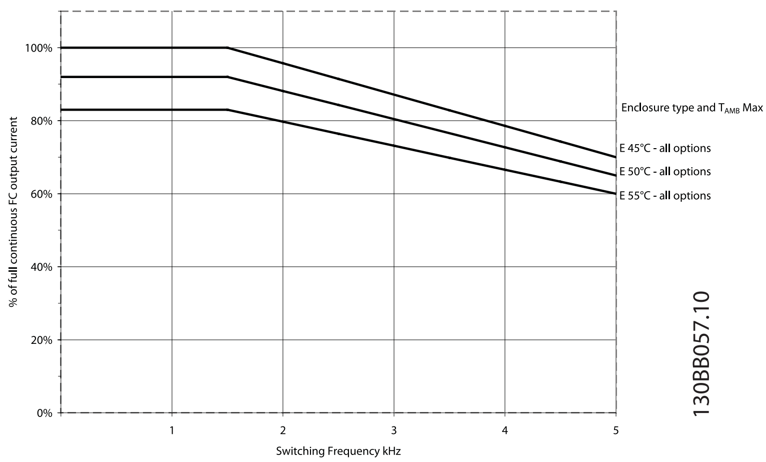

Illustration 1.9: E Enclosures 525-600V Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

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1.2.2 Applications with Specific Demands

The curves that follow in this section are applicable for the following applications:

- Screw, Scroll and Reciprocating Compressors where the switching pattern is changed from default (i.e. parameter 14-00 is changed to SFAVM).

A Enclosures

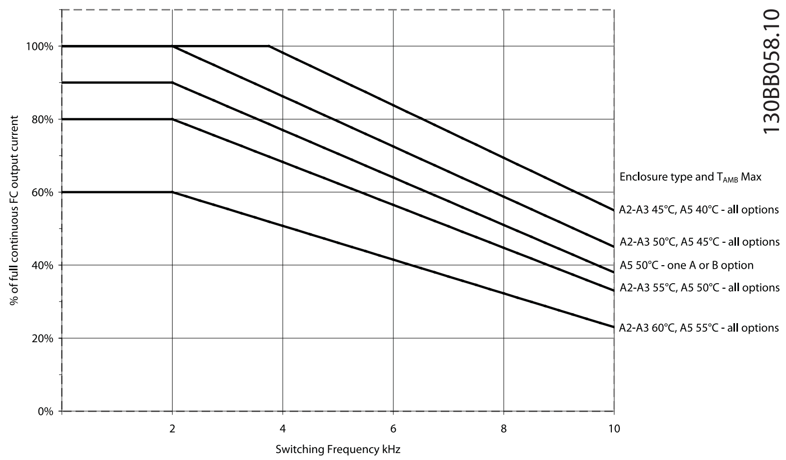

Illustration 1.10: A Enclosure Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

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B1 Enclosures

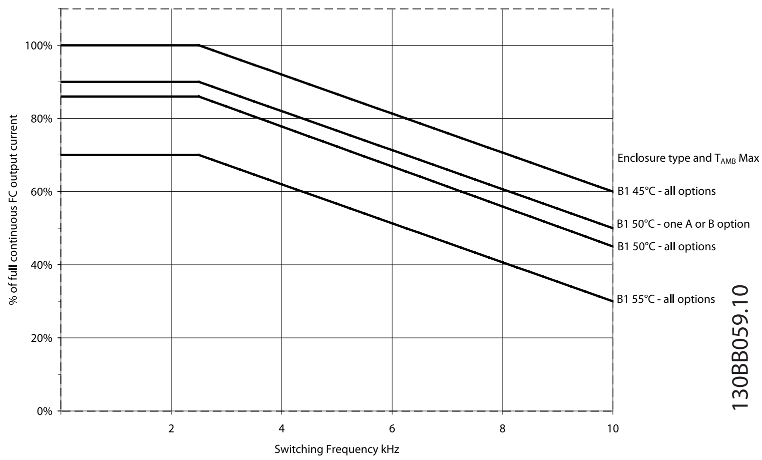

Illustration 1.11: B1 Enclosure Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

B2 Enclosures

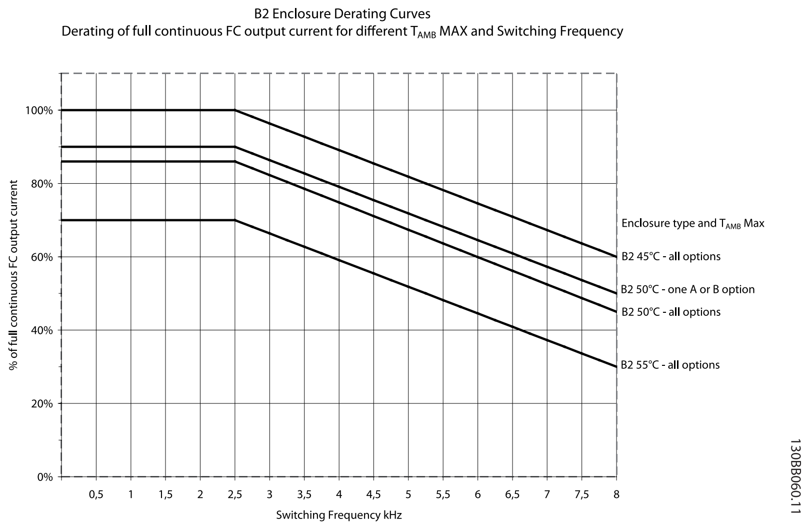

Illustration 1.12: B2 Enclosure Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

C Enclosures

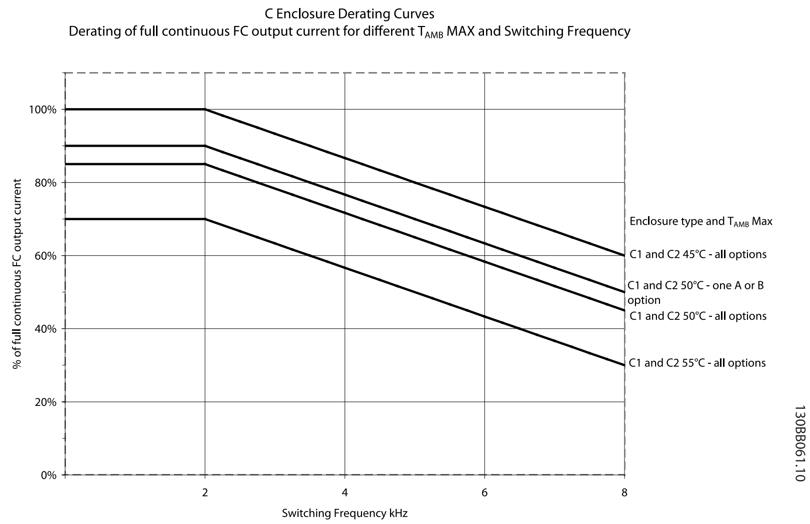

Illustration 1.13: C Enclosure Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

D Enclosures 380-480V

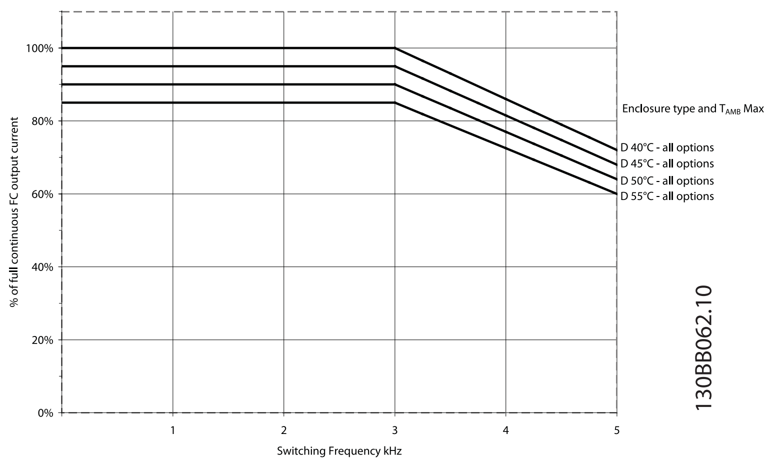

Illustration 1.14: D Enclosures 380-480V Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

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D Enclosures 525-600V excluding 315kW

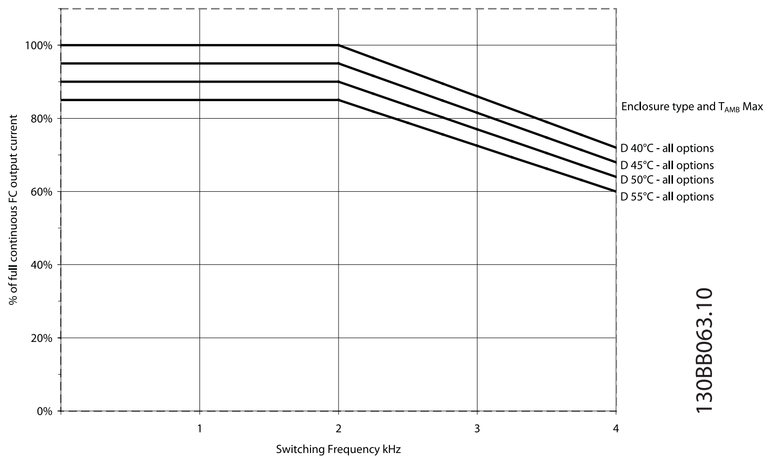

Illustration 1.15: D Enclosures 525-600V excluding 315kW Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

D Enclosure 525-600V 315kW

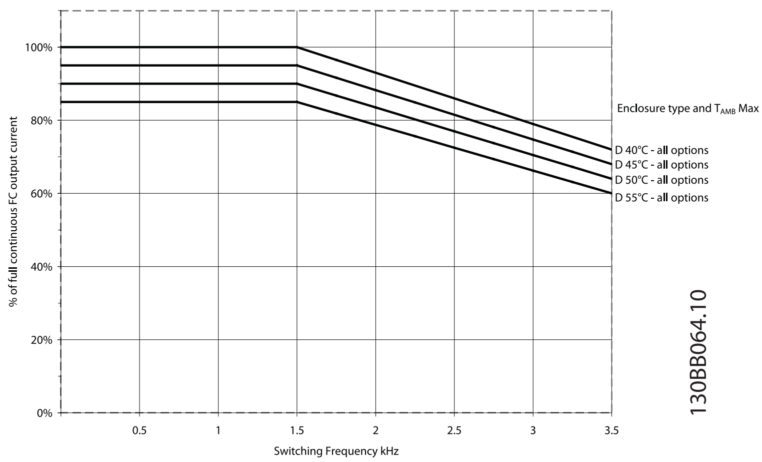

Illustration 1.16: D Enclosure 525-600V 315kW Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

E Enclosures 380-480V

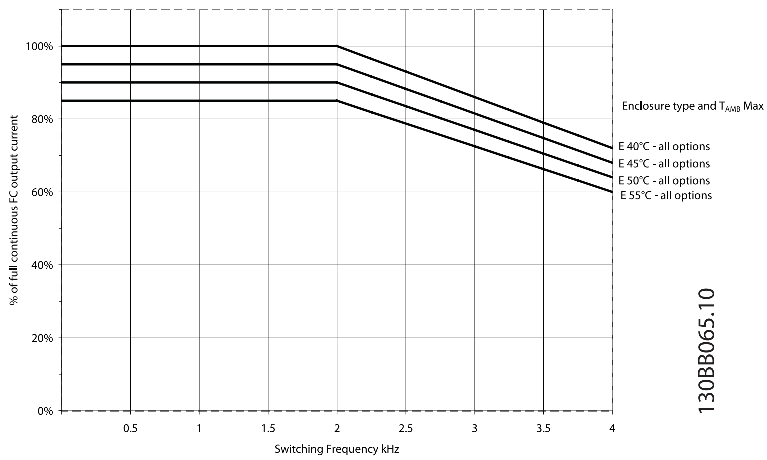

Illustration 1.17: E Enclosures 380-480V Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency

E Enclosures 525-600V

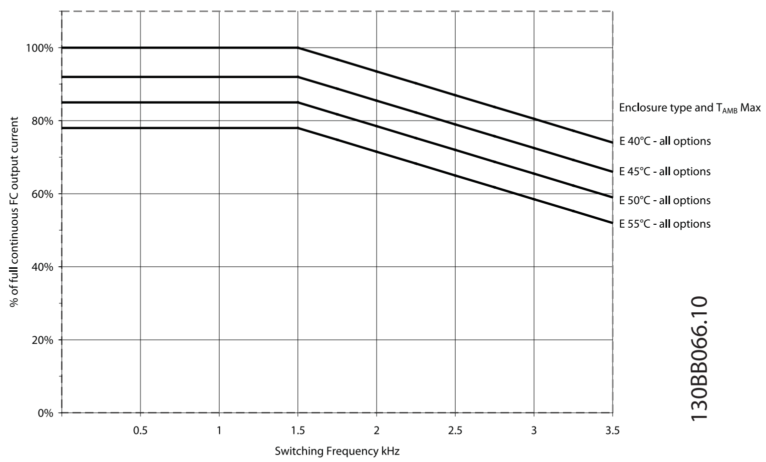

Illustration 1.18: E Enclosures 525-600V Derating Curves. Derating of full continuous FC output current for different T_{AMB} MAX and Switching Frequency