■ **Adjustment and size selection for the VLT 5000 series frequency converters connected to synchronous motors**

*Selecting the proper drive for synchronous motors*
The motor manufacturer, SSB, normally delivers 2 sets of U/F curves for the synchronous motor; one lower U/F ratio set for the max. torque at start equal to the nominal torque, and another higher U/F ratio set for a max. starting torque equal to 150% of the nominal torque. Both curves have the same U/F ratio at higher frequencies, but differ a few volts at the lower frequencies.

All motors for a specific application are manufactured (by SSB) with the same set of U/F ratio curves, therefore is it possible to connect the different motors in parallel. Even when the manufacturer matches the motors, a smaller motor should never have a lower voltage than a larger one which is connected in parallel. This is important if individual cables are used for each motor. See the following U/F ratio curves for 3 different synchronous motors manufactured by the company SSB:
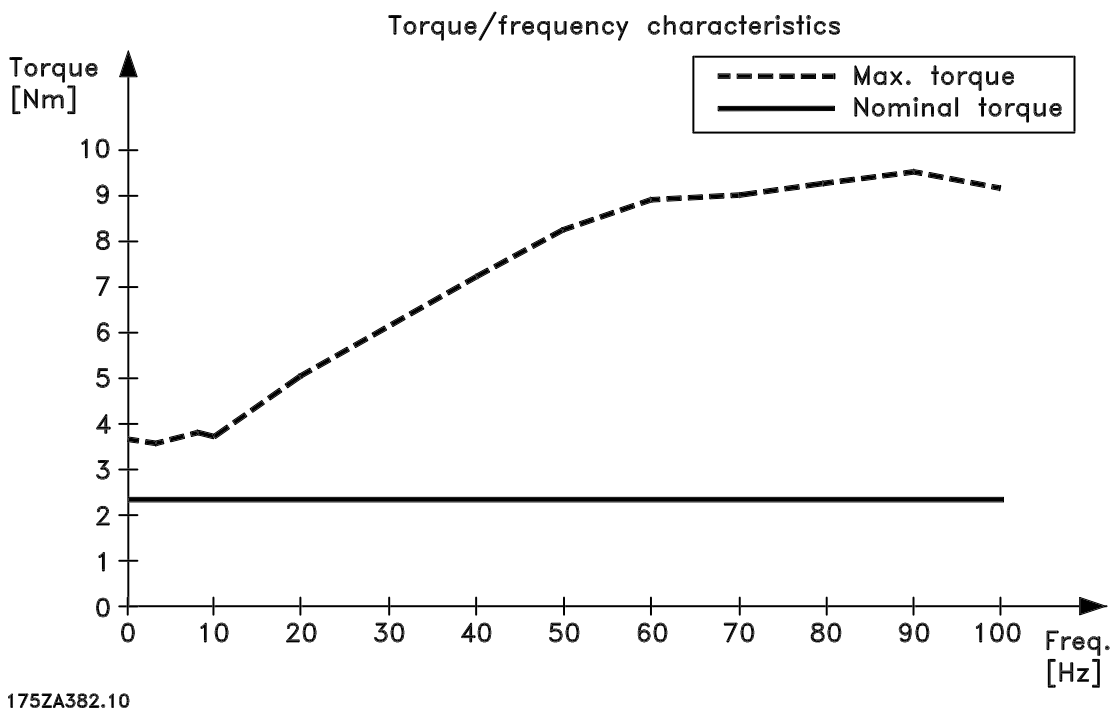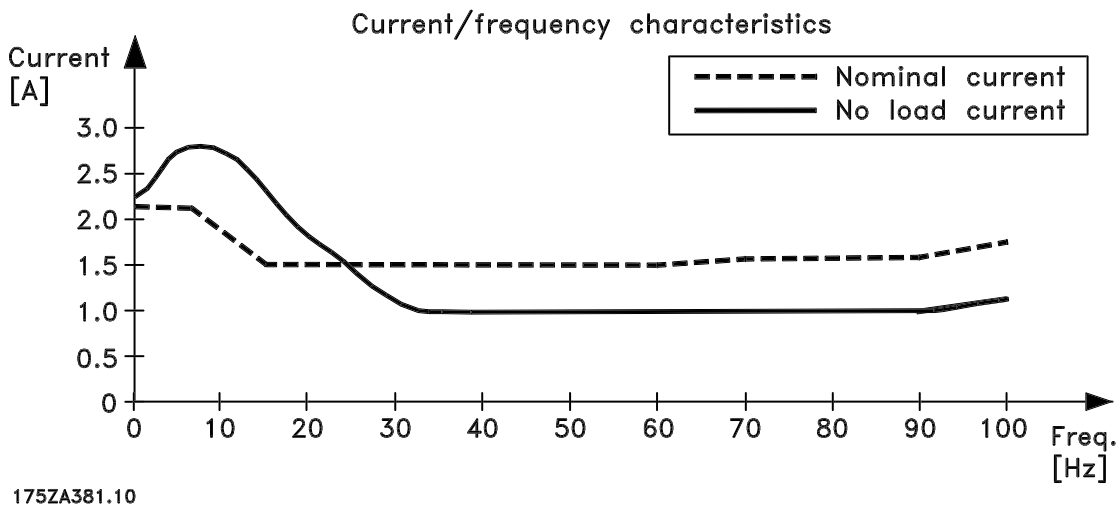
Fig. 1a:

Current/frequency characteristics

175ZA379.10

Torque/frequency characteristics
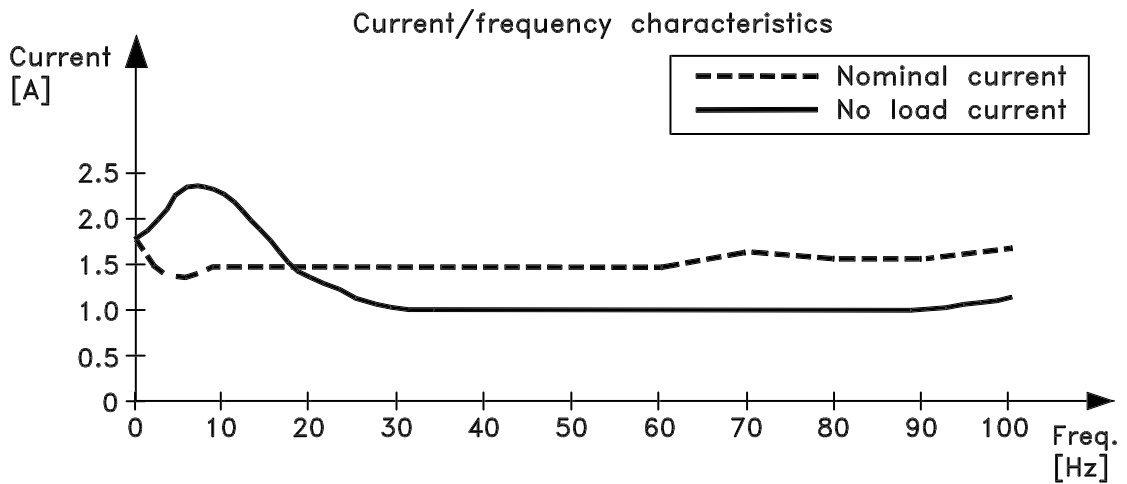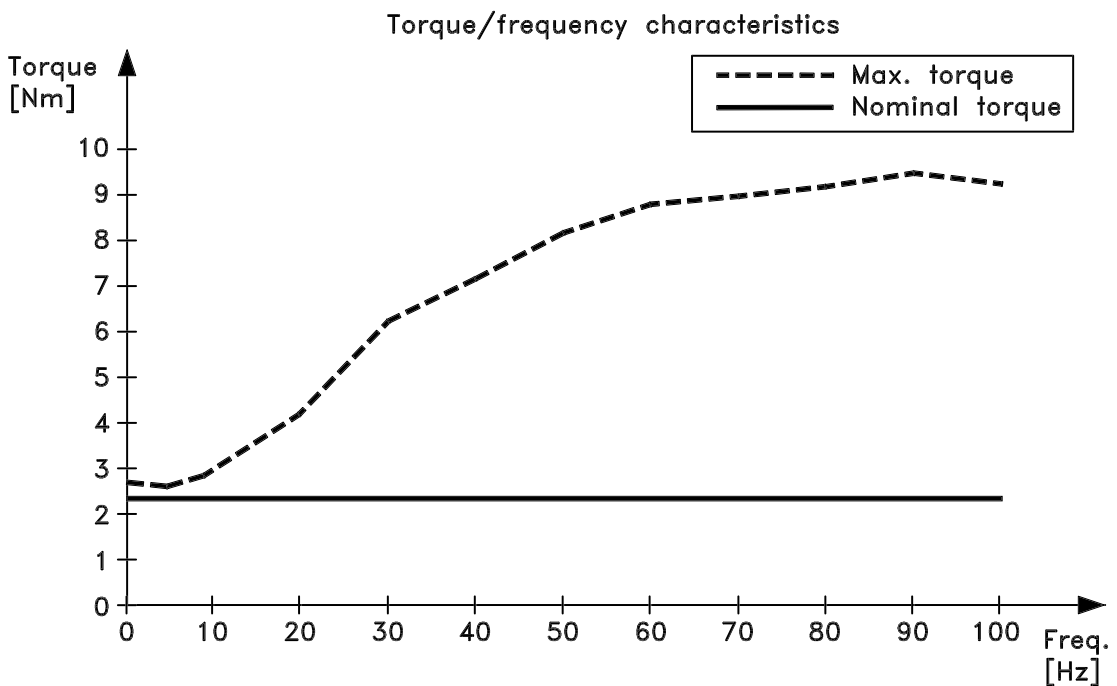
175ZA380.10

100 % torque curve for parallel synchronous motors from 0.75 kW to 4.0 kW (0.75 kW motor).

Selection of the Proper Drive for Synchronous Motors

Fig. 1b

Current/frequency characteristics

175ZA381.10

Torque/frequency characteristics

175ZA382.10

150 % torque curve for parallel synchronous motors from 0.75 kW to 4.0 kW (0.75 kW motor).

Fig. 2a

Current for 100 % torque curve for parallel synchronous motors from 5.5 kW to 30 kW (5.5 kW motor).

Fig. 2b

Current for 150 % torque curve for parallel synchronous motors from 5.5 kW to 30 kW (5.5 kW motor).

Selection of the Proper Drive for Synchronous Motors
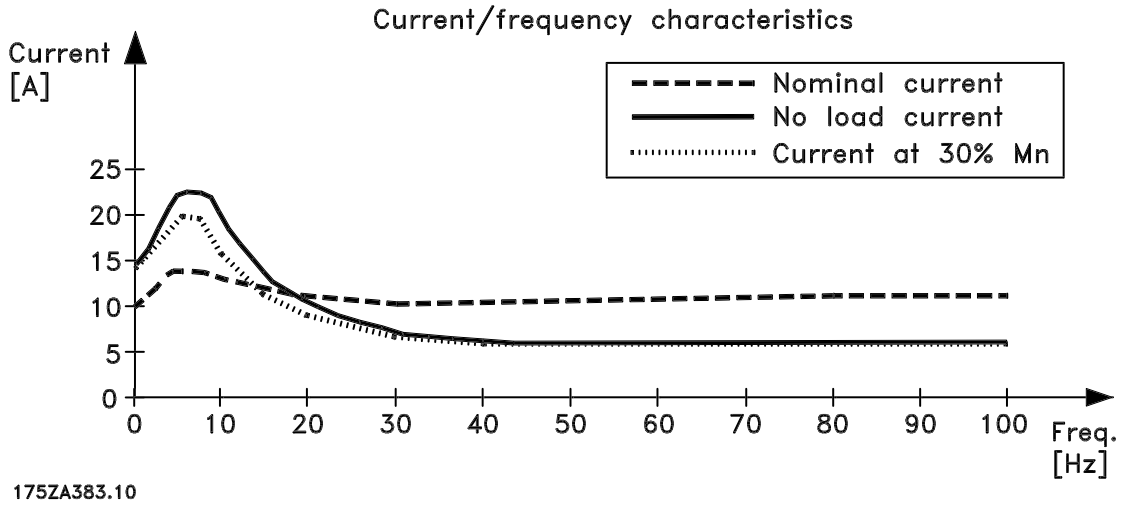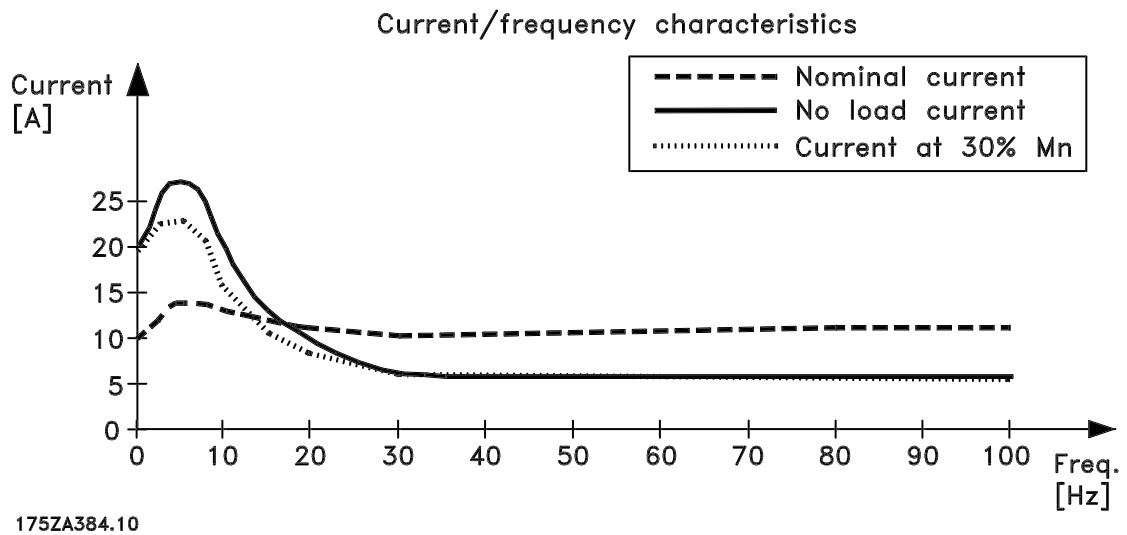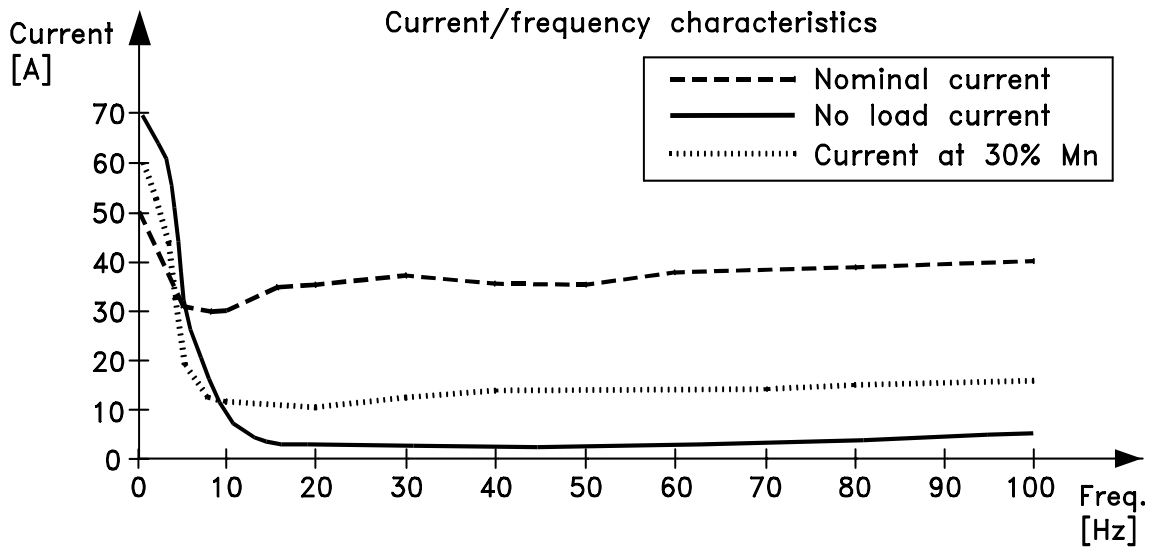
Fig. 3a

Current for 100 % torque curve for parallel synchronous motors from 5.5 kW to 30 kW (22 kW motor).

Fig. 3b
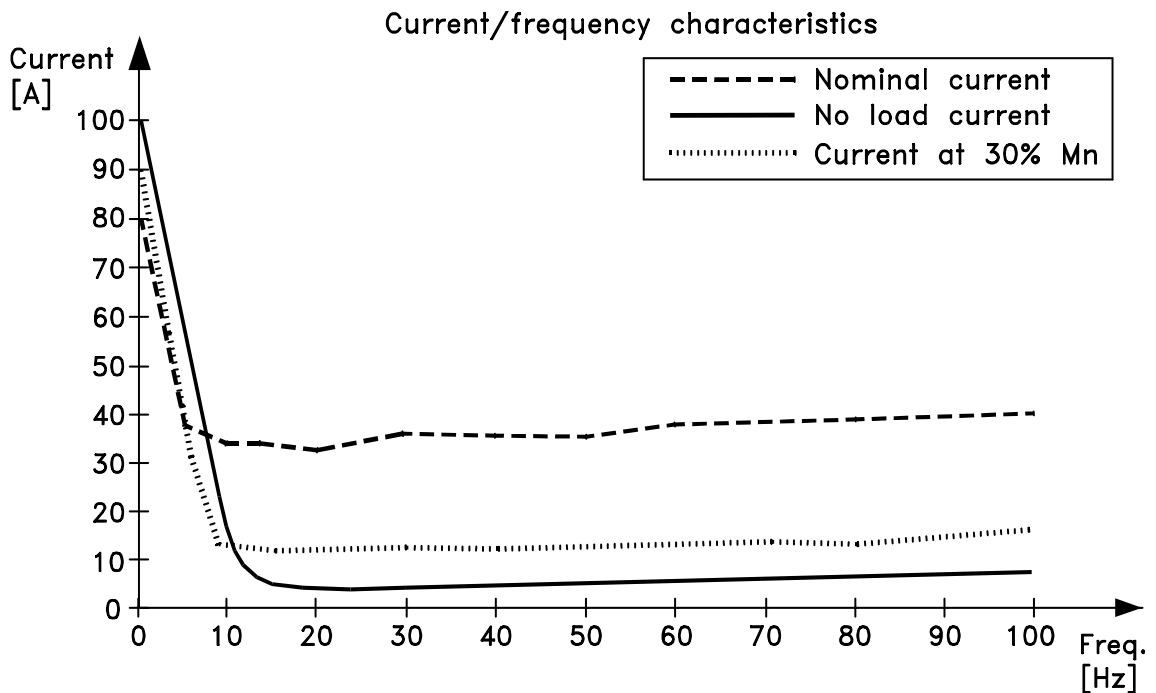
Current for 150 % torque curve for parallel synchronous motors from 5.5 kW to 30 kW (22 kW motor).

The curves above show that the no load current at low frequencies has the highest current rating which is about 2-3 times the nominal one.

NB!
Dimensioning for synchronous motors, should never be carried out based on kW rating, but must be done according to the combined highest current rating for the motors.

■ **Initial parameter setting for the VLT 5000**

All motor data must first be programmed for parameters P102 to P106:

P100: Maintain the factory setting (speed control open loop).

P102: Set the kW rating for the motor, if parallel motors are used, set the combined kW value.

P103: Set the nominal voltage for the motor(s).

P104: Set the nominal motor frequency (the nominal setting for synchronous motors is usually 100 Hz).

P105: Set the nominal motor current. If parallel motors are used, the combined motor current should be set.

P106: Maintain the factory setting for the rated motor speed (the value should correspond to the asynchronous speed of a 4 poled motor with a kW rating equal to P102 and running at 100 Hz).

⚠ **Do not** program the right synchronous speed for the 4 poled motor to 3000 RPM at 100 Hz, because the resonance dampening depends on a slip value. A slip value of 100 RPM can be set and P106 can be programmed to 2900 RPM.

P107: Here it is possible to perform a reduced AMA with measurement of Rs only, because the information will calculate an initial value for U_0, (U_0 = Rs x I nom.).

However, this value will probably be wrong and must be replaced by the manufacturer's information on settings for U_0.

P116: Experience has shown that a lower setting than the factory setting results in improved performance. The recommended setting is therefore 0.1 sec.

P117: Maintain the factory setting (100 %). An increase to 200-300% may be required later if resonance problems should arise.

P118: Maintain in factory setting.

P119: Maintain the factory setting in this parameter *high starting torque* at 0.0 sec. The parameter setting can later be increased to 0.5 sec. if additional start current is needed. However, when a current then reaches this higher level, the drive will be shut down.

☞ **NB!**
If any of the parameters P102 to P106 are changed later, the calculation of U_0 is changed and replaces a setting of P422 for U_0, therefore do not change these parameters after the initial settings.

P101: With the right dimensioning of the current for the VLT, select the *High-special motor characteristics* in P101. The slip regulation is automaticly disabled in this mode.

■ **Specific parameter settings for synchronous motors.**

When *Special motor characteristics* is selected in P101, parameters P422 to P433 are available for programming of the U/F curves according to the manufacturer's information. It is recommended to use the settings for the higher U/F curve with starting torque of 150%.

All the different voltage settings can be programmed individually (a negative U/F ratio could also be programmed if required), but the corresponding frequencies must be set in the right order, F1 before F2, F2 before F3, etc.

The calculation of U_0 at 0 Hz has already been done, but must be replaced by the manufacturer's information on settings (if no information is available, U_0 can be set at a voltage which gives about two times the nominal current for the motor).

The synchronous motors are all manufactured with the same settings, and the following table states the general settings for the three different motors shown above (information provided by SSB):

Voltage	/	Frequency
U_0 =10 V (P422)	/	0 Hz
U1 =10 V (P423)	/	F1 = 0.1 Hz (P424)
U2 =50 V (P425)	/	F2 = 10 Hz (P426)
U3 =105 V (P427)	/	F3 = 25 Hz (P428)
U4 =140 V (P429)	/	F4 = 35 Hz (P430)
U5 =400 V (P431)	/	F5 = 100 Hz (P432)

Table 1 for 100% starting torque. Parallel motors from 5.5 kW to 30 kW. U_0 : provided hold current.

Voltage	/	Frequency
U_0 =13 V (P422)	/	0 Hz
U1=13 V (P423)	/	F1 = 0.1 Hz (P424)
U2=50 V (P425)	/	F2 = 10 Hz (P426)
U3=105 V (P427)	/	F3 = 25 Hz (P428)
U4 =140 V (P429)	/	F4 = 35 Hz (P430)
U5 =400 V (P431)	/	F5 = 100 Hz (P432)

Table 2 for 150% starting torque. Parallel motors from 5.5 kW to 30 kW. U_0 : provided hold current.

Parameter Settings for Holding Torque for Synchronous Motors

The table shows that it is only a few volts which separate the 2 U/F curves at low frequencies, and this illustrates that the right voltage is important in order to obtain sufficient torque. Any voltage drops due to the use of long cables are critical, especially if separate cables with different cross sections and lengths are used for different motors which are connected to the same VLT output.

If no information is available on F1 to F5 voltage, all the frequencies to the nominal frequency (start with F5, then F4, etc.) should be set. After that the voltage U1 to U5 should be set to the nominal voltage. In this way a straight U/F curve between U_0 and the nominal values is established. Many motors will be able to run fairly well with this setting, however, a reduction of the voltage at the lower frequencies will normally result in improved performance and lower current, but specific guidelines are not possible.

■ **Parameter settings for holding torque for the synchronous motors**

Between start/stop sequences a holding torque is normally required which is easily established by stopping the rotating voltage vector. All the connected synchronous motors will still maintain the right angle synchronous relationship. However, if the motors are not forced ventilated, the holding current might overheat the motors. If it is required to stop the motors for an extended time, an electro-mechanical brake could take over the holding function. When an electromechanical brake or a holding current is used, the power must be turned off. A coast signal is sent to the VLT 5000 (terminal 27 = off) which sets the current to 0 and shuts the voltage vector off. When a new start is established, the voltage vector will start up arbitrarily, and the motors might change the relative angle to each other.

If only a single synchronous motor is connected to the output of the frequency converter, the DC-hold current mode or the DC brake current mode can be used for holding the motor. The DC brake current will automaticly stop after a certain programmed time as opposed to the DC-hold current which is present during the entire stop time.

If parallel synchronous motors are used, a fixed holding current is inconvenient and useless if the parallel motors can be disconnected individually. In this case, use the premagnetising setting which gives a fixed output voltage in special motor mode = U_0 in stopped mode.

A reasonable ramp time must also be set for the frequency converter, especially if a large inertia must be brought up to speed without losing synchronism due to too high acceleration torque demand.

NB!
Remember that the ramp time is the time up to nominal frequency which in this case normally is 100 Hz (this makes the ramp time twice as fast a normal ramp time).

The following situations can be programmed:

A: *Simple continued holding torque for a (single) motor connected to a VLT 5000:*
P122: Set the parameter to DC-hold.
P123: Maintain factory setting (0.0 Hz). When a stop signal is provided and the output frequency has been ramped down to 0 Hz, the DC-hold current will be reached.

Or:
P123: Set the parameter within the range from 0.1 to 0.2 Hz, when a permanent start signal is present and the external reference signal is ramped down to 0 Hz, the DC-hold current will be reached.
P124: Set the DC-hold current to an appropriate value (above 50%).

B. *Time limited holding torque for a (single) motor connected to a VLT 5000:*
P122: Set the parameter to *coast.*
P125: Set the DC brake current to an appropriate value (e. g. 100%, since the time is limited).
P126: Set the appropriate time for the holding current.
P127: Set the frequency at which the DC brake current is to be applied for holding motor torque .

C. *A combination of the two methods mentioned above for a (single) motor connected to a VLT 5000:*
P122: Set the parameter to DC-hold.
P123: Maintain factory setting (0.0 Hz). When a stop signal is provided and the output frequency has been ramped down to 0 Hz, the DC-hold current will be reached.

Or:
P123: Set the parameter within the range from 0.1 to 0.2 Hz, when a permanent start signal is present and the external reference signal is

ramped down to 0 Hz, the DC-hold current will then be reached.

P124: Set the DC-hold current to an appropriate value (above 50%).

P125: Set the DC brake current to an appropriate value (e. g. 100%, since the time is limited).

P126: Set the appropriate time for the holding current, provided by the brake current.

P127: Set the frequency at which the DC brake current is to be applied for increased holding motor torque.

It would be possible to apply an electromechanical brake during the DC brake current, when the motor is not in operation and with a reduced DC-hold current until next start, the angle synchrony will not be lost for the connected motor(s).

D. *Continued holding current for parallel motors connected to VLT 5000:*

P122: Set the parameter to premagnetising (holding current is now provided by U_0).

P422: Set the combined current to an appropriate value by adjusting U_0 (see the display).

NB!
Since U_0 determines the holding current, it is recommended that starting voltage (U_0 from the manufacturer) is set equal to U1 at F1 = 0.1 Hz.

■ **Further comments and parameter settings regarding resonance**

If the motor(s) show(s) resonance behaviour with strong varying current and unstable speed holding (particularly dominant for large efficient motors with negligible loss), then try to increase the setting for the resonance dampening P117. Since the resonance dampening uses the slip as basic calculation parameter, an increase in the slip might also be appropriate. The setting is made in parameter P106 (recommended setting is 2900 RPM = slip is 100 RPM for a 4 poled motor at nominal frequency of 100 Hz).

Resonance in the motor is also dampened by added loss, such as an increase in the resistance by use of long motor cables or mechanical friction loss from the working machine. The lower the switching frequency, the less the resonance in the motor. Therefore set parameter P411 to the lowest possible switching frequency. If parameter P446 is set to 60^0 AVM, resonance is reduced further, but this setting results in an increase in acoustic noise. It is recommended that the factory setting at SFAVM is maintained, only in case of resonance in the motor should the 60^0 AVM setting be used.
In case of unstable speed holding at the highest RPM, the overmodulation function can be disabled in parameter P413.

■ **Dimensioning of motor cable(s)**

As previously mentioned, the highest current is at low speed and no load condition, but since this running condition will only occur during a limited period of time, dimensioning of the cable size should be based on the nominal current for the motor. In applications with a single motor, an increase in the voltage setting for U_0 to U5 can compensate for the voltage drop across the cable.
The increase in the voltage can be calculated as the resistance of the cable multiplied by the no load current in the frequency setting point F_0 to F5 and then multiplied with $\sqrt{3}$, because the voltage setting is phase to phase.
The resistance for the cable is:
R = (0.0172 x L) / A in ohm.
L in meter. A in mm².

Example:
A 4 kW synchronous motor with 7.5 Amp. nominal current is run by a VLT 5008 by means of a 100 m cable with 4 mm² cross section. At 0 Hz the no load current is 15 Amp.
U_0 should be increased with :
Delta U=((0.0172 x 100)/4) x 15 x 1.732 = 11.2 Volt.
Corresponding points are calculated for F1 to F5, and added to the U/F curve.
The previous calculation is relevant for a single motor, or for a group of parallel motors with only a short cable to a common distribution point supplied by a long cable with a large cross section, where the voltage drop to the distribution point can be compensated for.

If all the parallel motors have individual cables with different cross sections adapted to the motor size, then the following recommendation applies:

A.:   First select the cable for the motor with the highest kW rating (see above for single motor, and calculate the voltage compensation needed to compensate this motor).

B.:   As previously mentioned small motors require a higher voltage than large motors. Therefore the voltage drop across the cable to the small motors should be less. Therefore approx. 10% should be deducted from the delta voltage previously found for the large motor, and the necessary cross section can now be calculated by means of the same formula:

$A = ((0.0172 \times L) \times I_{no\ load} \times \sqrt{3}) / delta\ U_{reduced}$

L in meter. I in Amp. U in volt. A in mm^2.

Example:

A 1.5 kW synchronous motor with 3.85 Amp. nominal current is connected in parallel to the 4 kW motor in the example above. The no load current is 8 Amp. and a 100 m cable is used. The voltage drop should then be approx. 11.2 x 0.9 = 10 volt.

The cross section calculation for:

$A = (0.0172 \times 100 \times 8 \times 1.732) / 10 = 2.38$ mm^2

A standard cross section of 2.5 mm^2 should then be selected.

Comments to the two parallel motors in the example above:

Since the delta compensation voltage for the 4 kW motor is fairly high, a cable with a larger cross section is a better choice, e.g. 6 mm^2. New calculations then give a delta voltage compensation of 7.4 volt. The voltage drop for the 1.5 kW motor is now 6.7 volt, and the cable cross section can now be calculated to $A = 3.55$ mm^2.

Select a standard 4 mm^2. However, cables with a larger cross section also cost more.