■ Note on hoists and the VLT 5000

This note provides additional information to the information on hoist applications found in the VLT 5000 manual, therefore the information in this note should be generally used in connection with hoist applications.

■ Special software

Danfoss developed a special crane software for the VLT 3000 series, the software had 2 U/F curves, one for hoisting and one for lowering. The same concept can be used for the standard software for the VLT 5000 series, where 2 different U/F ratios can be programmed into two separate setups for the special motor mode. One setup is then dedicated to hoisting and another to lowering. These 2 U/F curves in the 2 setups do, however, not compensate for load changes. This means that if the programmed setting is correct at no load, there will not be enough power to lift a heavy load; and if the programmed setting is correct for a heavy load, the motor will be over-compensated at no load. Therefore is it necessary to find a compromise for the U/F curves accounting for the lowest working temperature of the motor and the heaviest weight combined with the shortest ramp time. Since this setting is fairly difficult and time consuming, it is recommended to try the standard VVC+ mode first, possibly with some minor adjustments.

■ Temperature dependency

It is very important to set the right compensation in order to obtain max. hoisting/lowering performance especially at low RPM value.
In this case Rs (P108) plays a significant role in providing enough torque as well as an increase in magnetizing current setting (P110). Unfortunately the real Rs value for the motor changes with the temperature.
With a change in temperature of 100 °C, the change in stator resistance is approx. 40%. Therefore if a crane is exposed to a temperature of e.g. -40 °C, it will reach 80 °C when lifting heavy loads. In this situation the Rs will therefore change with up to 50%. Since there is no temperature compensation, a compromise must be found. If the torque is optimized when the motor is cold, the torque at low RPM will drop when the motor becomes warm and the Rs increases. If the setting is readjusted when the motor is warm, and the motor e.g. is shut down for the night, then the next morning when the motor is cold, the current will be too high at low RPM. This might result in an overcurrent warning or trip. This can partly be avoided by using a larger VLT.

NB!
This is the main reason why a VLT equal in size to the motor can only provide 80% torque for hoist applications.
If 100 % torque is required, a VLT which is one size larger than the motor should be used. Some approbation tests for cranes require an overload capability of 25%, this requirement might only be met by a VLT which is two sizes larger than the motor.

■ Electromechanical brake control

The electromechanical brake is controlled by the software in the VLT, and the VLT 5000 series is programmed to release the brake, when a start signal is given and the current exceeds a certain limit (set in parameter P223). Approx. 70% of the value of the magnetizing current is recommended based on general practice. However with certain motors and at generatoric running, this value can momentarily be much smaller and the brake will then close at full speed on the way down. In order to avoid this, the parameter might be set to an even lower value than above recommended (10-30%). When running in oversync. range, the magnetizing current will become lower. If P223 is set to 70% of the magnetizing current for 50 Hz (60HZ) and the unit runs up to 100 Hz (120Hz) with no load, then the magnetizing current is 50% of the previous value, and the brake has closed on the way up to the higher frequency. Only a lower setting in P223 can prevent this problem, but it also means that the brake is opened at a lower current, therefore extra precaution must be taken for the VLT to hold the motor before the brake opens. With fairly short ramps at start up and a higher value for P110 and P111, the VLT is able to hold the motor, before the electromechanical brake has opened (typical 100-300 mS.). See the following example:

-Nominal speed for the 50 Hz motor	= 1440 RPM.
-Slip in percent is:	
(1500 - 1440) x 100/1500	= 4%
-Slip frequency is 4% of 50 Hz	= 2 Hz.

It is recommended that the brake first opens, when the slip is at nominal value.

If the brake opens after 200mSec., the following calculation gives the recommended ramp time:
2Hz = 200mS
50Hz = 200mS x 25 = 5000mS; Set ramp up times to 5 sec.

If the same ramp down time is used, closing of the brake could be done at the same frequency. This means P225 is set to 2 Hz.

However if start delay functions is used, then there is no demand to specific ramp times.

The condition above is relevant for the "normal " mechanical brake control with constant supervision of the minimum current level. The output current can be very low (almost 0 Amp.) and the brake function will then close the brake, this condition is not acceptable and a new function was introduced, where the minimum current level (set in parameter P223) is only supervised in the start delay time. This setting is called "extended mechanical brake control". It is now possible to set a higher more relevant current level in P223, which must be exceeded before the brake is released.

NB !
The brake is not closed for the "extended mechanical brake control" if the connection between frequency converter and motor is interrupted (motor cable breakage or sudden contact failure).

The brake is closed if a trip occurs.
This condition can be used as added safety concerning failure of the dynamic brake function with brake resistor, because then the DC voltage will rise to the over voltage level. If parameter P410 (trip delay for the IGBT at over voltage) is set to 0 sec., then an immediate trip occurs closing the brake signal.

■ Start condition

In order to secure that the frequency converter is holding the motor before the electromechanical brake is released, then an output frequency can be applied during the "start delay time " set in parameter P120. The start delay time should be long enough to magnetize the motor, and is normally selected as the mechanical opening time for the electromechanical brake. Normal settings are 0.2 - 0.3 sec., but hydraulic brake can have opening times up to 1 sec.

The frequency is normally set equal to the slip of the motor for parameter P130.

In parameter P121 different start functions can be selected, and "VVC+ clockwise" can be recommended for crane applications and hoist applications without counterweight, because this will automatically calculate a voltage for the selected frequency in parameter 130.
Clockwise operation secures a starting torque which is always in the opposite direction of the torque caused by the weight of the load.

If a high starting torque is necessary for the application, then select "start frequency/voltage clockwise" in parameter P121; now a voltage can be set in parameter P131 for the selected frequency. For this adjustment of the voltage, set the time in P120 to 10 sec., and adjust the current to a level below the torque limit.
For lifts and other applications where a counterweight is present, "start frequency/voltage in reference direction" is normally selected for parameter P121, because the actual torque direction is not known after opening of the mechanical brake. Both parameters P130 and P131 must be set for this selection.

The function and activating time for the "high starting torque" in parameter P119 is moved to the end of the start delay period; in this way the added current allowance can be used for the acceleration torque for the selected ramp time.

NB !
Only software versions higher than 3.10 should be used with start delay functions.

■ U/F Ratio

The main problem with the use of VVC+ for crane applications occurs at low RPM in generatoric mode (lowering), because the current can suddenly become very high and result in an overcurrent situation.

When hoisting a heavy load, the compensation function will ensure that voltage is added to the basic setting to ensure the right performance. When lowering a heavy load at a fairly high RPM, the compensation function will ensure that voltage is deducted from the general setting to ensure the right performance. However, at <u>low RPM</u> the motor is inefficient and does not send generatoric current back to the VLT. The VLT therefore assumes that the motor is in motoric mode and reacts by suddenly **<u>adding</u>** the compensation voltage to the motor, which is still lowering a heavy load.
This wrong increase in compensation raises the current significantly, and only an oversized VLT can handle the situation (with heavy load).

In order to reduce the effect of this wrong compensation and avoid an overcurrent situation, a special setting for the VVC+ in one setup can be programmed or two setups in special mode can be used. One setup is programmed for raising U/F curve and the other setup is for the lowering U/F curve; setup shift is performed by the reversing signal based on the output frequency.

■ Premagnetizing

As mentioned before, with a low setting of P223 the VLT must hold the motor as quickly as possible before the brake is opened. Therefore time is gained when the motor is premagnetized at stop. This also helps to keep a steady temperature on the motor, lowering the trouble with Rs change (see the section on Temperature dependency). However, if premagnetizing is selected in parameter P122 during stop, then this value depends on the setting of the magnetizing current in parameter P110. It is therefore recommended to use a DC-hold current in P122 during stop.

■ Recommended setting for hoist applications

All data for the motor must first be programmed. Then an AMA run (P107) on a cold motor should be carried out. 10% might be added to the value found for Rs to compensate for an increase in temperature, and about 5% might be deducted for Xs, in order to sligtly increase the basic magnetizing current.
Remember to set parameter P200 to both directions, select the max. reference frequency for parameter P205 (and set parameter 203 to –max to +max, if reversing is based on negative ref. signal). Select appropriate ramp up/down times in parameters P207 and P208.

If the standard settings for the frequency converter do not provide the necessary torque for the lift application, then the following 3 improvements is suggested for implementation:

1. Improved dynamic performance:

Set parameter P116 (slip compensation time constant) to a lower value. Approx. 0,1 sec. is recommended. This setting should also be used, even when the slip is set to 0% or closed loop operation is used, all the following improvements should also have this lower value.

2. Improved VVC+ settings for one setup:

Because the current increases at low generatoric speed, where the automatic voltage compensation is added instead of deducted from the no-load curve, then this condition is minimized by setting the automatic voltage compensation parameters P113 and P114 to a low value. However then the general torque is also lowered, and to counteract this condition, the Rs is increased and Xs reduced.

Settings based on motor equivalent diagram:
Multiply the Rs value with a factor of 1.4, and set this value in parameters P108 for stator resistance. (If a long motor cable is used, then the cable resistance must first be added to the stator resistance before the multiplication).
Multiply the Xs value with a factor of 0.8, and set this value in parameter P109 for the stator reactance.
Set parameters P113 and P114 to 60%.

Settings based on AMA measurement of the motor parameters:
Perform the AMA measurement on a “cold” motor, and record the values in parameters P108/109.
Multiply the value in parameter P108 with 1.4 and replace the value in parameter P108 with this new value.
Multiply the recorded value in parameter P109 with 0.7 to 0.5 and set this new value in P109 (normally the AMA measured value is higher than for the equivalent motor diagram, therefore this lower multiplication factor, but start with 0.7 times).
Set parameters P113 and P114 to 60%.

Remember to set P116 to the recommended 0.1 sec. (because adjustment of P108/109 resets P115/116 etc. to factory setting)

Further increase in P108 values raise the torque, but increase the current, and at low temperature this could bring the frequency converter into current limit. Testing or calculation can determine the min. temperature for the present setting, because for each 10° Celsius reduction, the current increases with about 4 %.

3. Different U/F settings for hoisting and lowering mode in 2 setups:

Based on the motor equivalent diagram information, the U/F curves can be calculated for hoisting mode as well as lowering mode and with different load and temperatures. The curves are fairly different at low RPM, but have the following general feature:

Hoisting U/F curve is a straight line from the U0 at 0Hz up to nominal voltage at nominal frequency. In special mode the hoisting U/F curve is set to nominal voltage for U1 to U5, and nominal frequency for F1 to F5. U0 is precalculated, but must normally be increased significantly to meet max. torque demand. With no load and at the lowest temperature, the value of U0 is increased (parameter P422) until the current at 0 Hz is just below the torque limit (set in parameter P221 as 95% of max. setting).

Lowering U/F curve is a straight line from about 2 times the slip frequency and up to about 90% of the nominal voltage at nominal frequency. The voltage at about 2 times the slip frequency is close to the voltage determined for U0. There is a minimum voltage approximately equal to the slip frequency and with a value close to half the U0 settings. Intermediates frequencies and voltages can then be set for the curve up to about 2 times the slip frequency. Following U/F setting therefore applies:

Set F5 to nominal frequency.
Set U5 to 90% of the nominal voltage for the motor.
Set F4 to 2 times the slip frequency.
Set U4 equal to U0 (determined during hoisting setting).
Set F3 to 1.5 times the slip frequency.
Set U3 to 75% of U0.
Set F2 equal to the slip frequency.
Set U2 equal to 50% of U0.
Set F1 to 0.5 times the slip frequency.
Set U1 to 75% of U0.
Set U0 to the same value as for hoisting.

The suggestions above apply for a torque demand of about 100 %, if higher torque is desired then replace the slip frequency with the corresponding higher slip frequency (150 % torque demand increases the slip frequency by approx. 1.5 times). The voltages U5 to U0 are not changed by the higher torque demand.

Now program the U/F curve for hoisting in setup 1 and the U/F curve for lowering in setup 3 in special motor mode (parameters P422 to P432). Choose multi setup (parameter P004) and use the output reverse signal from terminal 42 or 45 (parameter P319 or P321) to change the set up. Use e.g. factory set MSB input on terminal 32 as input for the output signal 42 or 45; the reverse signal will change from setup 1 to setup 3 at lowering.

Determine the lowering current at nominal frequency with max. load, and readjust the current to this value at the frequencies F1 to F4, by raising or lowering the U1 to U5 values at the measuring frequency.

■ Cone rotor motor (Demag motor)

When using cone rotor motors, the brake is part of the motor construction and is permanently closed and fail-safe, when no power is applied. Only when a sufficient magnetic field is created in the motor, is the rotor pulled in and the brake opened. The recommended setting above also applies for the cone rotor motor, except those parameters relating to the control of relay 01 or 04 for the electromecanical brake control. However, it is not possible to run a normal Rs, Xs AMA function, because the air gap is large during the test, and a false Xs value will be measured (if at all). Instead the Rs measurement with the AMA function should be run. The right Rs setting and the increased setting for P110, which could be as high as 200%, is important. Once the rotor has been pulled into the stator by the increased magnetic field, the operation of the motor will be fairly normal.

■ Closed loop

It is a general misunderstanding that operation in closed loop mode with encoder feedback will give a higher holding torque at low RPM. Closed loop will be able to hold a load for an extended period of time (without closing the brake), but closed loop will not provide a better short term holding performance, than a good dynamic slip regulation based on internal current feedback in open loop .

Setting parameters for closed loop is normally based on site trials, and therefore the optimum setting is not always found. The performance might therefore be lower than in open loop mode (slip compensation is 0 in closed loop mode), but the same improved settings for open loop can be used for closed loop.
A VLT which has the same size as the motor can typically provide only 70%-80% holding torque when operating in closed loop mode.