Drivecon

MOTOR DRIVES AND CONTROLS

GRAB CONTROL

Owner's Manual

CONTENTS

1 General

This document describes the functional properties of the Grab Control and provides information for the use of a Grab controlled crane. Also the information for maintenance and service is given.

The Grab Control is designed for grab unloaders and other cranes, where a mechanical grab is operated by the two rope system. The Grab Control consists of two Inverter Vector controllers with closed loop control and a programmable logic controller, PLC. The selection of components like limit switches, sensors, joysticks, buttons, lamps etc. may vary case by case because they are designed separately for each project.

The machinery designed for the Grab Hold is exactly the same as for the Grab Close. The Grab Hold and the Grab Close machinery are each driven by the squirrel cage induction motor, with the separate variable frequency controller Inverter Vector. The speed of each motor is measured by an incremental pulse encoder that is mounted on the motor shaft. The signals from each encoder are fed directly to the associated Inverter as a speed feedback to the vector control. The same signals are also fed to a pulse counter in the master PLC for position measurement. Both the Grab Hold and Grab Close machinery contain a mechanical brake. Each brake is controlled by the corresponding Inverter.

The PLC reads the commands and reference signals given by the user. The calculations for the speed reference and correction values are carried out in the PLC and the resulting signals are forwarded to the Inverters. All normal slow down and stop limit switches and interlocks operate via the PLC software.

2 Functional Description

2.1 Duty Cycle in General

The normal manually controlled duty cycle consists of the steps introduced here below. It should be noted that only the operations related to the Grab Hold and Grab Close drives are presented here.

Grab Lowering
The opened grab is driven down towards the material by lowering both drives. Ideally the PLC provides the same speed reference value for both Inverter. However, if the grab begins to open or close when only lowering is requested, the PLC automatically corrects the position of the grab. If the crane operator wants to open or close the grab during lowering giving the reference by the joystick, the PLC gives different speed references for each drive resulting the grab to open or close.

Grab Stop
During lowering the empty grab, when the PLC detects the slack rope condition on the Grab Hold drive, a fast stop is applied to both Grab Hold and Grab Close Inverter.

Grab Filling
The grab is filled by raising the Grab Close drive. At the same time, the Grab Hold drive is lowered to enable the sinking of the grab, but keeping some tension on its ropes by using the torque control mode of the Grab Hold Inverter. The PLC monitors the position of the grab jaws using the encoder signals, slows the closing speed accordingly when the grab is almost closed, and then starts raising the closed grab automatically.

Grab Raising
During raising the loaded grab, the PLC balances the loads between the Grab Hold and Grab Close Inverters. In the case of the closed grab, the PLC gives the same speed reference for both Inverters. As the feedback from the motor drives the PLC reads the calculated torques and provides the correction to balance the torques.

Grab Emptying
The grab is emptied by lowering the Grab Close drive. The PLC monitors the position of the grab jaws using the encoder signals, slows down the opening speed accordingly when the grab is almost opened, and then stops the opening when the grab is totally opened.

2.2 Automatic Operations

The Grab Control contains several automatic features that are developed for grab applications. Some features are within the Inverters but most of them are implemented in the PLC software.

Synchronization
When just raising or lowering of the empty grab is desired, the grab should not open or close. To ensure that the position of the grab jaws remains constant during these operations, the PLC measures the position of both Grab Hold and Grab Close machinery and carries out the position synchronization. If a position error appears the PLC calculates the correction and adds the correction to the speed references given to the Inverters. However, if the crane operator wants to open or close the grab during raising or lowering giving the reference by the joystick, the PLC provides different speed references for each drive. When the opening or closing of the grab is completed the position synchronization is active again.

Field Weakening
The field weakening feature of each Inverter allows its motor to run at higher than the nominal speed when the load is lower than the rating. In the Grab Control, the field weakening is used during the raising and lowering of the empty grab and also when opening or closing the grab. The use of field weakening is automatically controlled by the PLC based on the weighing, the motor torque outputs of the drives and the status of the grab.

Grab Fast Stop

When the grab is landed onto the material the ropes tend to get slack because the deceleration of the drives is restricted by the ramps. To avoid excessive slack rope the Grab Control detects automatically when ropes get slack while lowering the grab. Both machineries are then stopped using fast ramps.

Load Balancing
When the grab full of material is being raised or lowered, the loads of the Hold and Close motors are balanced by the Grab Control. This ensures that the Hold motor also participates in the hoisting part of the grabbing cycle and increases its share of the duty. The PLC controls the load balancing by calculating the correction for each Inverter. This correction signal is given to the drives separately from the speed reference signal

because the correction must be fast acting and not limited by the acceleration or deceleration limits that are built into each Inverter. The correction signal has no rate limits in the Inverter, but has amplitude limits instead.

2.3 Grab Hoist Limits

It should be noted that the type of limit switch sensors and the functions may vary in different projects. The selected sensors and their use should be confirmed from the electrical drawings. The description here below presents one common solution.

For each Hold and Close drum, there are usually four limit switches that are operated by the drum mechanism. All limit switches are also wired to the PLC even though some functions are hardwired.

Two rotary limit switches are used for slow down function. These limit switches operate at either end of the full speed working range of the drive and define the starting positions for the deceleration in the slow down functions. The deceleration can be carried out by deactivating the slow down inputs of the Inverters or the PLC can provide deceleration ramps in the speed references for the drives.

In the PLC, there are "software" limits for the normal stop functions. These "software" limits are determined based on the encoder measurements. The slow down speed is calculated according to the actual position and slow down ramp so that the machinery stops smoothly when the machinery reaches the "software" stop limit.

The other two rotary limit switches are used for emergency stop limit functions. These switches operate in the winding direction just before the rope couplings reach the pulleys or the drum, and in the unwinding direction if only the friction turns of the ropes remain on the drum.

S1E Hardwired emergency stop limit for up direction, rotary limit switch, connected to Inverter to stop the motion

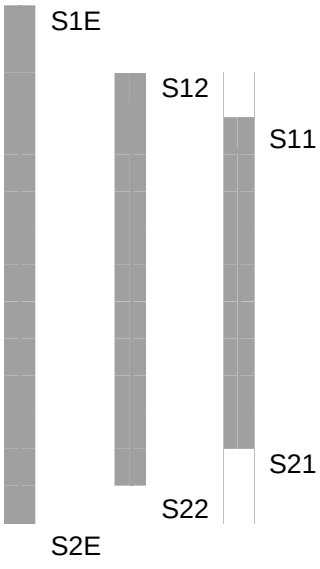
S12 Software calculated stop limit for up direction, PLC controls Inverter to stop

S11 Rotary slow down limit switch for up direction, PLC reduces the speed reference and the slow down input of Inverter is deactivated

S21 Rotary slow down limit switch for down direction, PLC reduces the speed reference and the slow down input of Inverter is deactivated

S22 Software calculated stop limit for down direction, PLC controls Inverter to stop

S2E Hardwired emergency stop limit for down direction, rotary limit switch, connected to Inverter to stop the motion



2.4 Grab Open and Closed Limits

For the opening and closing motion of the grab, it is not possible to have hardware limit switches. This is because the grab opening is only a function of the position difference between the Close and Hold drives.

Therefore the slow down and stop limit functions of the closing motion have to be carried out in the PLC. The maximum slow down speed is calculated continuously according to the actual position difference and ramp so that the closing motion stops when the grab reaches the Closed or Opened limit.

Only the grab Closed and grab Opened limits have to be set. The PLC automatically adjusts the slow down limits accordingly.

2.5 Supervision Functions

Emergency Stop
For an emergency stop, the drives are turned off. This further means that the power to each motor is removed and the mechanical brakes are engaged immediately. The hardwired emergency system is designed separately for each application.

NOVA (One for Each Drive)
Both the Hold and Close Inverters include the NOVA modules which monitor the operation of both drives separately. Based on the measured speed of the motor, three independent supervision functions are applied: overspeed, stall and speed difference supervisions. If any fault is detected by a NOVA module both Inverters are directly stopped.

Thermal Protection of Motor Windings (One for Each Motor)
Both Hold and Close motors are equipped with thermistors wired to Inverters. If too high temperature is detected, motions are stopped. Further running is inhibited until the motor temperatures are again below the limit of the thermistors.

Brake control supervision
The PLC monitors that the drives actually energize the brake contactors when run commands are given. The feedback of the brake control for the PLC is given by the status of the Inverter brake contactors K7.

Inverter Trip
Each Inverter has several internal supervision systems (see Inverter manuals for details). The signals to the PLC confirm that the drives are OK (no faults). In any fault situation, both Inverters are stopped.

Overload Protection
The sensors used for the crane overload protection are designed separately for every project. The PLC reads the sensors and controls the overload functions. The overload protection can be common for the Hold and Close machinery or both ones can have their own protection.

Position Measurement
The PLC monitors that the grab position calculated based on the encoder pulses is correct. The check point is at the slow down limit for up direction (rotary limit switch).

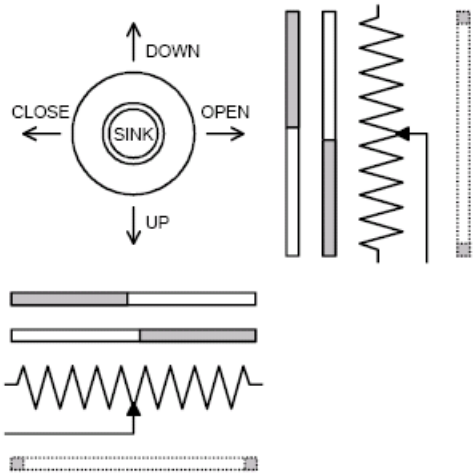
3. Operating Instruction

Note! The user interface may be customized for projects and thus the instructions given here may be invalid regarding the customized features.

3.1 Grab Command Joystick

All of the grab operations are commanded from a twin axis proportional joystick. One axis is for raising-lowering and the other axis is for opening-closing, so that both motions can be commanded at the same time. The joystick is spring-loaded to return to its center (neutral) position.

The joystick includes potentiometers for both axis, direction contacts, push-button, and possibly full speed contacts.



Potentiometers for Proportional Deflection Measurements
For each axis, the joystick has a potentiometer to measure the extent of the deflection from the center (neutral) position. These proportional signals are connected to PLC analog inputs.

Deflection Direction Contacts
For each axis, the joystick has two contacts to sense the direction of deflection. When the joystick is in the center (neutral) position, these contacts are open. The signals are connected to PLC inputs.

"Full Speed" Contacts (Optional)
If required, the joystick can also have "full speed" contacts connected to PLC inputs. These can be useful if the joystick reaches its maximum mechanical deflection before the potentiometer output signal is at the full range of the corresponding PLC analog input. When a full speed command is received, the PLC reads the request value of the full speed, independent of the value of the corresponding analog signal from the joystick.

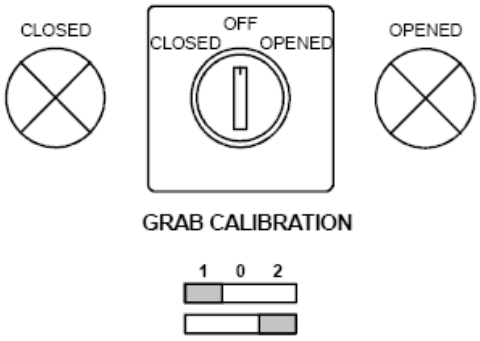
"Sink bypass" Push-Button
The joystick has a push-button on the top of its knob to bypass the grab sinking mode.

Joystick Initial Position Check
When turning the crane ON or after a fault, the PLC checks that the joystick has first been in its center (neutral) position before any motion can be started. This ensures that there are no unexpected grab movements when the crane is switched ON or when a fault is cleared.

3.2 Grab Limit Calibration

Grab Calibration Controls and Indications
Before the grab can be opened or closed (at other than limited speed), the operating range of its jaws must be calibrated. For the calibration, the grab jaws are driven to each end of their range and the corresponding position is defined by the operator's action.

For the Grab Control, there is a 3-position selector switch and two indicator lamps for the grab calibration. These are located on the operator's control console. The selector switch is off in the center position and has two contacts for the selected direction. The switch contacts are connected to the PLC inputs. The indicator lamps are energized by the PLC outputs.



When the grab limits are being calibrated, the raising-lowering axis of the joystick controls Hold machinery and opening-closing axis controls Close machinery directly without any compensation or PLC correction (the speed is limited).

Grab Closed Limit
The Closed limit is set with the following sequence:

1. Turn the selector switch to the CLOSED position.
2. Adjust the grab by using the command joystick so that the grab is just closed. While this mode is selected, the stop limits for the grab opening and closing are disabled to permit the adjustment. The grab opening and closing speeds are limited to allow precise adjustment and to avoid mechanical damage.
3. When the grab jaws touch each other, turn the switch from CLOSED to OFF. The Closed limit is set here and the CLOSED indicator lamp should be illuminated.

The CLOSED indicator lamp has the following states:

Flashing rapidly	Closed position not calibrated or position measurement fault.
Flashing slowly	The grab jaws have been jammed.
Off	Grab NOT at Closed limit.
On	Grab at Closed limit.

Grab Opened Limit
The Opened limit is set with the following sequence:

1. Turn the selector switch to the OPENED position.
2. Adjust the grab by using the command joystick so that the grab is just opened. While this mode is selected, the stop limits for the grab opening and closing are disabled to permit the adjustment. The grab opening and closing speeds are limited to allow precise adjustment and to avoid mechanical damage.
3. When the grab jaws are in the desired position, turn the switch from OPENED to OFF. The Opened limit is set here and the OPENED indicator lamp should be illuminated.

The OPENED indicator lamp has the following states:

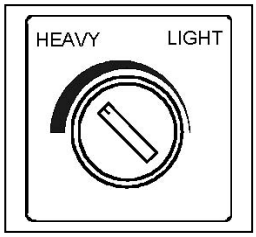
Flashing rapidly	Opened position not calibrated or position measurement fault.
Off	Grab NOT at Opened limit.
On	Grab at Opened limit.

Calibration Fault Detection
If the PLC is switched off or reset, the position calibrations are lost and the steps listed above must be repeated for both grab Closed and Opened limits.

3.3 Load Optimizing

To completely fill most mechanical grabs, the Hold machinery must be lowered slightly during the closing sequence. If the grab becomes suspended by the hold ropes, it does not fill completely. To avoid this problem, the Grab Control can maintain a small constant torque on the Hold machinery during the grab closing.

The reference value for the rope tension of the Hold machinery is given by the load optimization potentiometer. If the rope tension is too large the grab does not sink into the material freely resulting in a light grab load. On the other hand with a small tension the grab load becomes heavy but too small value may get the Hold rope slack.



LOAD OPTIMIZATION

3.4 Driving the Grab Control

Automatic Grab Filling Sequence
To optimize the duty cycle the Grab Control has an automatic grab filling sequence. It is activated by deflecting the joystick to raising-and-closing direction. Then the operation of the Grab Control is as follows:

1. The grab is closed with controlled sinking keeping the tension given by the load optimization potentiometer in the Hold machinery ropes.
2. The closing speed is reduced when the software slow down limit for the crab closed direction is reached. The grab raising is started when the grab is closed.
3. In raising the closed grab, the loads of the Hold and Close machinery are balanced.

If the button on the top of the joystick is pressed during the sequence, the speed reference value of the Hold machinery given with the joystick is forwarded to the Hold Inverter thus overriding the automatic sinking. This might be useful if the grab is sinking too deep in the material.

It should be noted that if the empty grab suspended by both Hold and Close ropes is closed without bypassing the automatic sinking, the grab lowers slowly. The reason for that is that the small rope tension in the Hold ropes allow the Hold machinery to run downwards. The amount of lowering is dependent on the geometry of the grab.

The Slack Rope Condition and Fast Stop
During normal operation, the maximum acceleration and deceleration are specified by the Inverter parameters. However, when lowering the empty grab onto the material, it is advantageous to stop the motion as fast as possible to prevent excessive slack rope, thus making the loading sequence faster. In the Grab Control, when the slack rope condition is detected, the faster deceleration ramps for both drives are selected by a digital input. The deceleration time with the fast stop is about 20% of the normal deceleration time. The PLC monitors the slack rope condition and it also activates the fast deceleration.

During the slack rope condition grab lowering and opening are disabled. Pressing the sink bypass button bypasses the slack rope condition and allows lowering and opening also when ropes are slack.

Grab Jammed Detection
If the material is very rough or unhomogenous, some object may get stuck between the grab jaws. Then the grab starts raising before it is actually closed. The Grab Control detects this situation comparing the speeds of the Hold and Close drives. The jammed grab is indicated by blinking the CLOSED indicator lamp slowly for five seconds. The operator can then decide if he wants to go on raising or try and refill the grab.

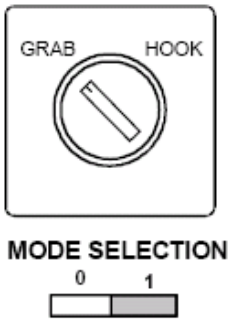
Field Weakening
In the Grab Control, the field weakening is used during the raising and lowering of the empty grab and also when opening or closing the grab. For safety use of field weakening the load must be known. When the crane includes a weighing system the grab must be weighed each time after calibrating the Closed or Opened limits. Only limited speed is possible before the grab weighing.

Driving Both Motions at the Same Time
All combinations of driving both motions – raising or lowering and grab opening or closing – simultaneously are possible in the Grab Control.

Lowering and opening	The needed speed difference between the drives is provided by increasing the speed of the Close drive, or if this is not possible because of the maximum speed limit by decreasing the speed of the Hold drive.
Raising and closing	The needed speed difference between the drives is provided by increasing the speed of the Close drive, or if this is not possible because of the maximum speed limit by decreasing the speed of the Hold drive.
Lowering and closing	The closing is carried out by decreasing the speed of the Close drive.
Raising and opening	The opening is carried out by decreasing the speed of the Close drive.

3.5 The Hook Mode

It is possible to remove the grab and use the Grab Control to lift a hook, spreader or some other load lifting attachment. A special HOOK mode is available and is selected by a selector switch. When the HOOK mode is selected, the position difference of the Hold and Close drives is stored as a reference. In the HOOK mode the Hold and Close drives are synchronized so that the position difference remains constant all the time. Note that the opening-closing axis of the joystick has no function while the HOOK mode is active. Note also that the motions must



Note! After changing the mode back to the GRAB mode, the grab Closed and Opened limits must be recalibrated according to the instructions given in Chapter 3.2.

4 Service and Maintenance

4.1 Start-up

Start-up procedure:

1. Energize the main contactor and switch on the control system
2. Make sure that the mode selection is correct
3. Make sure that the limit calibration is correct
4. Check the position of the load optimizing potentiometer

4.2 Grab change

In changing the grab the operator can bypass the slack rope condition by pressing the button on the top of the joystick. This action allows lowering and opening also with slack ropes. It may also be helpful to drive in the grab limit calibration mode (the selector switch in CLOSED or OPENED position) to avoid problems with the grab Closed and Opened limits. When one of the calibration modes is selected the raising-lowering axis of the joystick controls the Hold machinery and opening-closing axis controls the Close machinery directly with the limited speed. After changing the grab, the Closed and Opened limits must be recalibrated according to the instructions given in Chapter 3.2.

4.3 Changing the ropes

In changing the ropes it is also possible to bypass the slack rope condition by pressing the button on the top of the joystick and it may be useful to select the grab calibration mode to run the drives separately.

Note! After changing the ropes the first run to the upper slow down rotary limit calibrates the encoder positions. After that the Closed and Opened limits must be set according to Chapter 3.2.

4.4 Operation in Fault Situations

Position Measurement Fault
When the grab is driven to the upper slow down limit for the first time, the encoder position is stored. Thereafter, when the grab is driven to the same slow down limit, the measured position is compared to the stored one. If the positions differ from each other too much, the position measurement fault is activated and the new position value is stored. If a position measurement fault is detected, the grab Closed and Opened limits must be recalibrated (see Chapter 3.2).

Overload
If the maximum load of the crane is exceeded, hoisting and grab closing are tripped immediately. Then, only downward motion is allowed until the load is below the overload limit.

Motor Drive Fault
If a motor drive fault occurs in either of the Inverters, both drives are tripped. If the cause of the fault is removed and the joystick is brought to center position, the operation is allowed to continue. See Inverter manuals for more detailed information.

NOVA
If overspeed, stall or speed difference is detected by the NOVA, the main contactor must be switched off and back on before it is possible to continue running.

Wire Break
If a wire break is detected in any analog signal, all motions are stopped immediately. Operation may continue when all signals are OK.

Grab does not open or close
If the mode selection is set to the HOOK mode, the Hold and Close drives run with the same speed. Make sure that the GRAB mode is selected. Check also the encoder position calibration and the calibration of the grab Closed and Opened limits.

Rope Winding Fault
If the crane is equipped with sensors to detect a rope winding fault, the problems in winding and unwinding the ropes into the drums can be detected. If a rope winding fault occurs both machineries are stopped immediately. Driving to up direction is disabled until the position where the rope winding fault was detected has been passed. The speed to down direction is limited to the slow down speed.