

Operating Guide

VLT® Extended/Advanced Cascade Controllers MCO 101/MCO 102

VLT® AQUA Drive FC 202



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1 Introduction

1.1 Purpose of the Operating Guide

The purpose of this Operating Guide is to describe the VLT® Extended Cascade Controller MCO 101 and VLT® Advanced Cascade Controller MCO 102. The Operating Guide contains information about:

- Applications for cascade control.
- Installation.
- Configuration of the system.
- Parameters.
- Configuration examples.

The Operating Guide is intended for use by qualified personnel. To use the cascade controller options safely and professionally, read this Operating Guide thoroughly and pay particular attention to the safety instructions and general warnings.

1.2 Trademarks

VLT® is a registered trademark for Danfoss A/S.

1.3 Additional Resources

Various resources are available to understand advanced drive operation, programming, and directives compliance.

- The VLT® AQUA FC 202 Operating Guide provides detailed information for the installation and start-up of the drive.
- The VLT® AQUA FC 202 Programming Guide provides greater detail on how to work with parameters. It also contains application examples.
- The VLT® AQUA FC 202 Design Guide provides detailed information about capabilities and functionality to design motor control systems.
- Supplemental publications, drawings, and manuals are available at www.danfoss.com.

Contact a Danfoss supplier or visit www.danfoss.com for more information.

1.4 Document and Software Version

This manual is regularly reviewed and updated. All suggestions for improvement are welcome.

The original language of this manual is English.

Table 1: Document and Software Version

Edition	Remarks	Software version
AQ326832164524, version 0101	<ul style="list-style-type: none"> • Editorial update. 	VLT® Extended Cascade Controller MCO 101: 2.6X VLT® Advanced Cascade Controller MCO 102: 1.2X

N O T I C E

The Cascade Controller options for the VLT® AQUA Drive FC 202 are supported in the VLT® AQUA Drive software version 1.24 and onwards.

1.5 Product Overview

The VLT® Extended Cascade Controller MCO 101 and VLT® Advanced Cascade Controller MCO 102 are add-on options extending the supported number of pumps and the functionalities of the built-in Cascade Controller in the VLT® AQUA Drive FC 202.

The MCO 101 consists of an option board with 3 relays and is installed in slot B. Once the options are installed, the parameters supporting the Cascade Controller functions are available via the LCP in *parameter group 27-** Cascade CTL Option*.

The following options for cascade control are available in the VLT® AQUA Drive FC 202:

- Built-in Basic Cascade Controller (standard Cascade Controller)
- VLT® Extended Cascade Controller MCO 101
- VLT® Advanced Cascade Controller MCO 102

The MCO 101 and MCO 102 can be used in 2 different modes:

- With the extended features controlled by *parameter group 27-** Cascade CTL Option*.
- Extending the number of available relays for the Basic Cascade Controller via *parameter group 25-** Cascade Controller*.

With MCO 101, a total of 5 relays can be used for cascade control. With MCO 102, a total of 8 pumps can be controlled. The options are able to alternate the lead pump with 2 relays per pump.

NOTICE

If the MCO 102 is installed, the VLT® Relay Card MCB 105 can extend the number of relays to 13.

1.5.1 Intended Use

Cascade control is a common control system used to control parallel pumps or fans in an energy-efficient way.

The VLT® Extended Cascade Controller MCO 101 and the VLT® Advanced Cascade Controller MCO 102 are designed for pump applications, however, it is also possible to use Cascade Controllers in any application requiring multiple motors configured in parallel.

The MCO 101 and MCO 102 enable control of multiple pumps configured in parallel by:

- Automatically turning individual pumps on/off.
- Controlling the speed of the pumps.

When using Cascade Controllers, the individual pumps are automatically turned on (staged) and turned off (destaged) as needed to meet the required system output for flow or pressure. The speed of pumps connected to the VLT® AQUA Drive FC 202 is also controlled to provide a continuous range of system output.

The Cascade Controller software runs from a single drive with a Cascade Controller option installed (master drive). It controls a set of pumps, each controlled by a drive or connected to a contactor or a soft starter.

Other drives in the system (follower drives) do not need to have a Cascade Controller option card installed. They are operated in open-loop mode and receive the speed reference from the master drive. Pumps connected to drives are referred to as variable-speed pumps. Pumps connected to mains through a contactor or through a soft starter are referred to as fixed-speed pumps.

Each pump, variable speed or fixed speed, is controlled by a relay in the drive. The MCO 101 and MCO 102 can control a mix of variable-speed and fixed-speed pumps.

NOTICE

VLT® Digital Cascade can be used instead of MCO 101 and MCO 102 for master/follower applications for full redundant system. The VLT® Digital Cascade control is unlocked with a license code. Installation is easy using embedded Modbus RTU and multi-master ability makes system redundant. Example: If the master breaks down, the back-up master takes its place until a replacement takes place.

2 Safety

2.1 Safety Symbols

The following symbols are used in this manual:

⚠ D A N G E R ⚠
Indicates a hazardous situation which, if not avoided, will result in death or serious injury.
⚠ W A R N I N G ⚠
Indicates a hazardous situation which, if not avoided, could result in death or serious injury.
⚠ C A U T I O N ⚠
Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.
N O T I C E
Indicates information considered important, but not hazard-related (for example, messages relating to property damage).

2.2 Qualified Personnel

To allow trouble-free and safe operation of the unit, only qualified personnel with proven skills are allowed to transport, store, assemble, install, program, commission, maintain, and decommission this equipment.

Persons with proven skills:

- Are qualified electrical engineers, or persons who have received training from qualified electrical engineers and are suitably experienced to operate devices, systems, plant, and machinery in accordance with pertinent laws and regulations.
- Are familiar with the basic regulations concerning health and safety/accident prevention.
- Have read and understood the safety guidelines given in all manuals provided with the unit, especially the instructions given in the Operating Guide.
- Have good knowledge of the generic and specialist standards applicable to the specific application.

2.3 Safety Precautions

⚠ W A R N I N G ⚠
HIGH VOLTAGE
AC drives contain high voltage when connected to AC mains input, DC supply, or load sharing. Failure to perform installation, start-up, and maintenance by qualified personnel can result in death or serious injury.
– Only qualified personnel must perform installation, start-up, and maintenance.

⚠ W A R N I N G ⚠
UNINTENDED START
When the drive is connected to the AC mains, DC supply, or load sharing, the motor may start at any time, causing risk of death, serious injury, and equipment or property damage. The motor may start by activation of an external switch, a fieldbus command, an input reference signal from the LCP or LOP, via remote operation using MCT 10 Set-up software, or after a cleared fault condition.
– Press [Off] on the LCP before programming parameters.
– Disconnect the drive from the mains whenever personal safety considerations make it necessary to avoid unintended motor start.
– Check that the drive, motor, and any driven equipment are in operational readiness.

⚠ WARNING ⚠

DISCHARGE TIME

The drive contains DC-link capacitors, which can remain charged even when the drive is not powered. High voltage can be present even when the warning indicator lights are off.

Failure to wait the specified time after power has been removed before performing service or repair work could result in death or serious injury.

- Stop the motor.
- Disconnect AC mains, permanent magnet type motors, and remote DC-link supplies, including battery back-ups, UPS, and DC-link connections to other drives.
- Wait for the capacitors to discharge fully. The minimum waiting time is specified in the table *Discharge time* and is also visible on the nameplate on top of the drive.
- Before performing any service or repair work, use an appropriate voltage measuring device to make sure that the capacitors are fully discharged.

Table 2: Discharge Time

Voltage [V]	Minimum waiting time (minutes)					
	4	7	15	20	30	40
200–240	0.25–3.7 kW (0.34–5 hp)	–	5.5–45 kW (7.5–60 hp)	–	–	–
380–480	0.37–7.5 kW (0.5–10 hp)	–	11–90 kW (15–125 hp)	110–250 kW (150–335 hp)	–	315–1500 kW (425–2000 hp)
525–600	0.75–7.5 kW (1.0–10 hp)	–	11–90 kW (15–125 hp)	–	–	–
525–690	–	1.1–7.5 kW (1.5–10 hp)	11–90 kW (15–125 hp)	45–400 kW (60–540 kW)	450–1200 kW (600–1600 hp)	1400 kW (1875 hp)

⚠ WARNING ⚠

LEAKAGE CURRENT HAZARD

Leakage currents exceed 3.5 mA. Failure to ground the drive properly can result in death or serious injury.

- Ensure the correct grounding of the equipment by a certified electrical installer.

⚠ WARNING ⚠

ROTATING SHAFTS

Contact with rotating shafts and electrical equipment can result in death or serious injury.

- Ensure that only trained and qualified personnel perform installation, start-up, and maintenance.
- Ensure that electrical work conforms to national and local electrical codes.
- Follow the procedures in this guide.

⚠ WARNING ⚠

UNINTENDED MOTOR ROTATION WINDMILLING

Unintended rotation of permanent magnet motors creates voltage and can charge the unit, resulting in death, serious injury, or equipment damage.

- Ensure that permanent magnet motors are blocked to prevent unintended rotation.

▲ C A U T I O N ▲**INTERNAL FAILURE HAZARD**

An internal failure in the drive can result in serious injury when the drive is not properly closed.

- Ensure that all safety covers are in place and securely fastened before applying power.

3 Applications

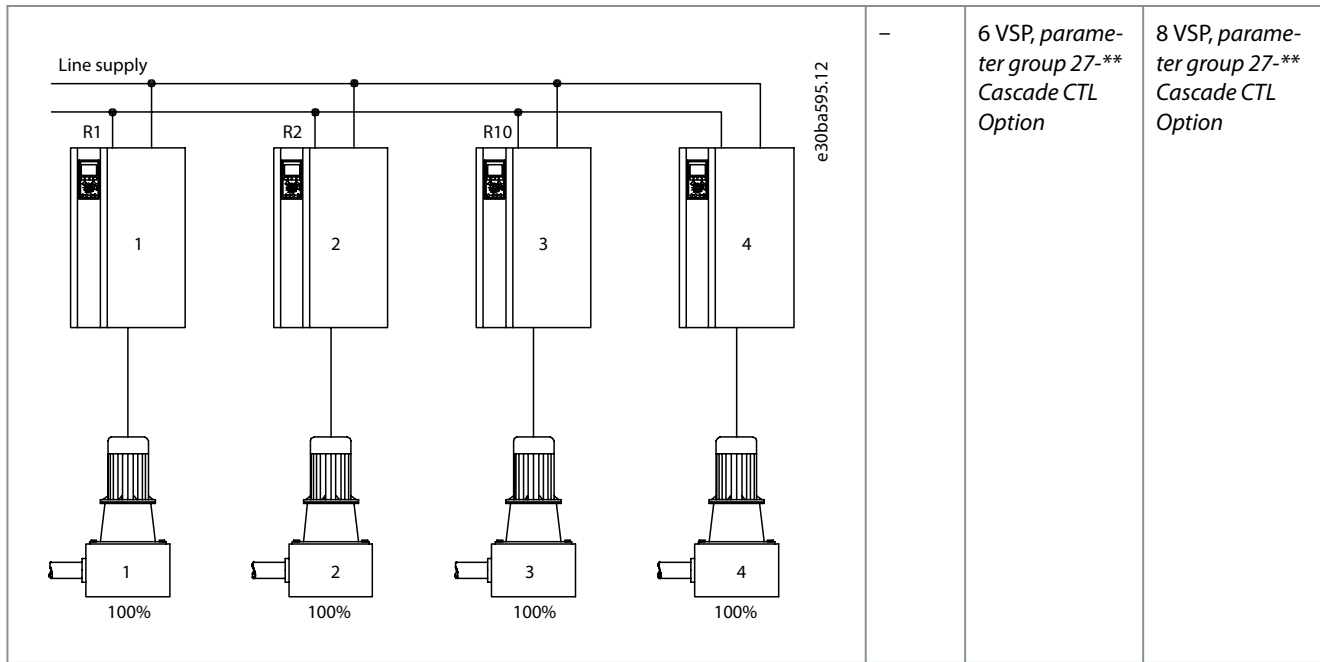
3.1 Application Overview

	Built-in	MCO 101	MCO 102
<p style="text-align: right;">e30ba594.12</p>	<p>1 VSP⁽¹⁾ + 2 FSP⁽²⁾, parameter group 25-** Cascade Controller</p>	<p>1 VSP + 5 FSP, parameter group 25-** Cascade Controller</p>	<p>1 VSP + 8 FSP, parameter group 25-** Cascade Controller</p>
<p style="text-align: right;">e30ba593.12</p>	<p>–</p>	<p>1–6 VSP + 1–5 FSP (maximum 6 pumps), parameter group 27-** Cascade CTL Option</p>	<p>1–8 VSP + 1–7 FSP (maximum 8 pumps), parameter group 27-** Cascade CTL Option</p>

¹ VSP=Variable-speed pump (directly connected to the drive).

² FSP=Fixed-speed pump (the motor could be connected via contactor, soft starter, or star/delta starter).

	Built-in	MCO 101	MCO 102



3.2 Supported Configurations

When setting up the system, create a hardware configuration which communicates the number of connected pumps and drives to the master. The necessary hardware is explained in the hardware configuration examples.

3.2.1 Hardware Configuration for Expanding of Basic Cascade

In applications already controlled by the built-in Cascade Controller in *parameter group 25-** Control Mode*, the option cards can be used to extend the number of relays for cascade control, for example, if a new pump is added to the system.

To enable the basic Cascade Controller in *parameter 27-10 Cascade Controller*, select [3] *Basic Cascade Ctrl*. Refer to VLT® AQUA Drive FC 202 Programming Guide for further programming with settings from *parameter group 25-** Control Mode*.

Refer to [Illustration 1](#) and [Illustration 2](#) for examples of external wiring required for systems with alternating lead pump of 4 pumps using basic cascade and VLT® Extended Cascade Controller MCO 101 as relay extension.

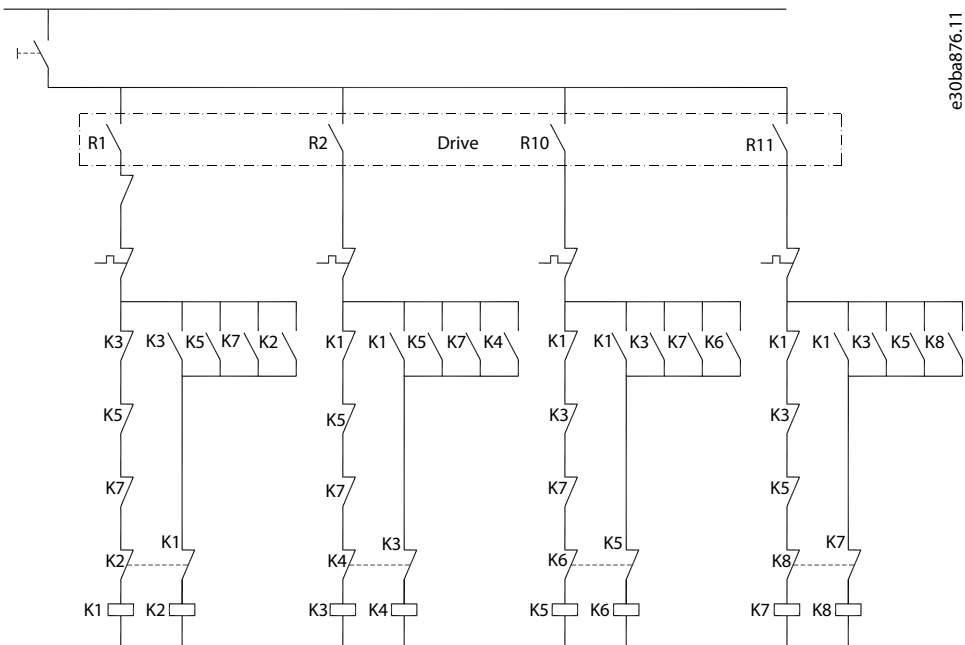


Illustration 1: Control Circuit Alternating Lead Pump (4 Pumps)

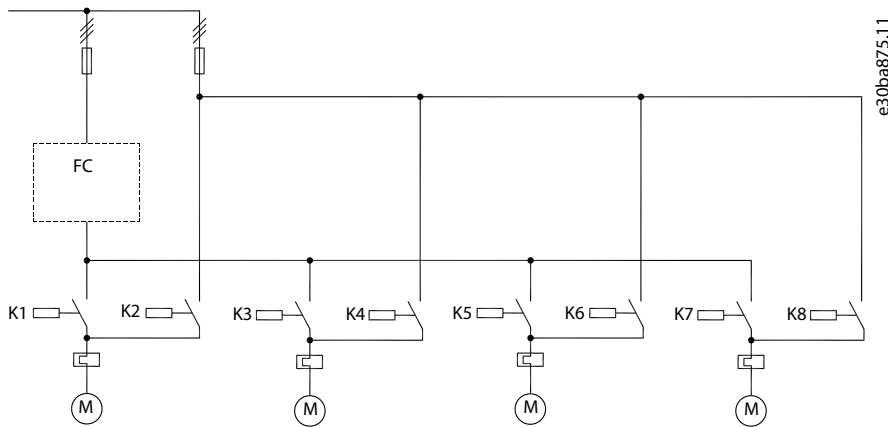


Illustration 2: Mains Circuit Alternating Lead Pump (4 Pumps)

The fixed-speed pump configuration provides a cost-effective method for controlling up to 9 pumps. It is able to control system output by controlling the number of running pumps and the speed of the single variable-speed pump.

In this configuration, the VLT® AQUA Drive FC 202 with a VLT® Advanced Cascade Controller MCO 102 controls 1 variable-speed pump and up to 8 fixed-speed pumps. The fixed-speed pumps are staged and destaged as needed through contactors direct online. The variable-speed pump provides the finer level of control needed between the stages.

The direct online pumps are staged or destaged depending on their feedback.

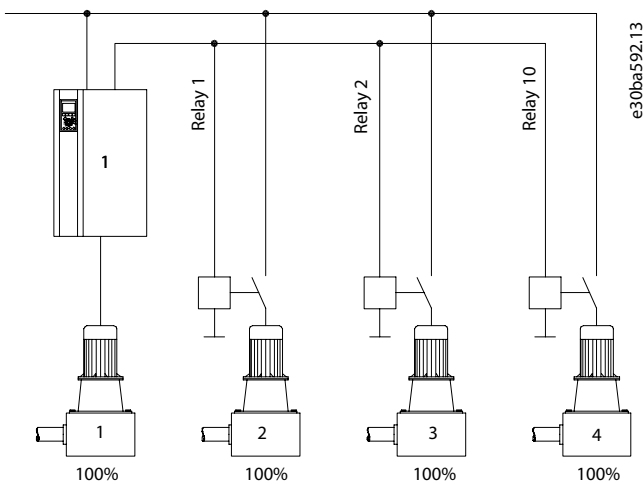


Illustration 3: Fixed-speed Pump Configuration Example

NOTICE

If the pumps are not equal in size or if 2 relays per pump are used, a mixed-pump configuration must be selected in *parameter 27-10 Cascade Controller*. For the configuration shown in [Illustration 3](#), relay selections in *parameter group 27-7* Connections* are as follows:

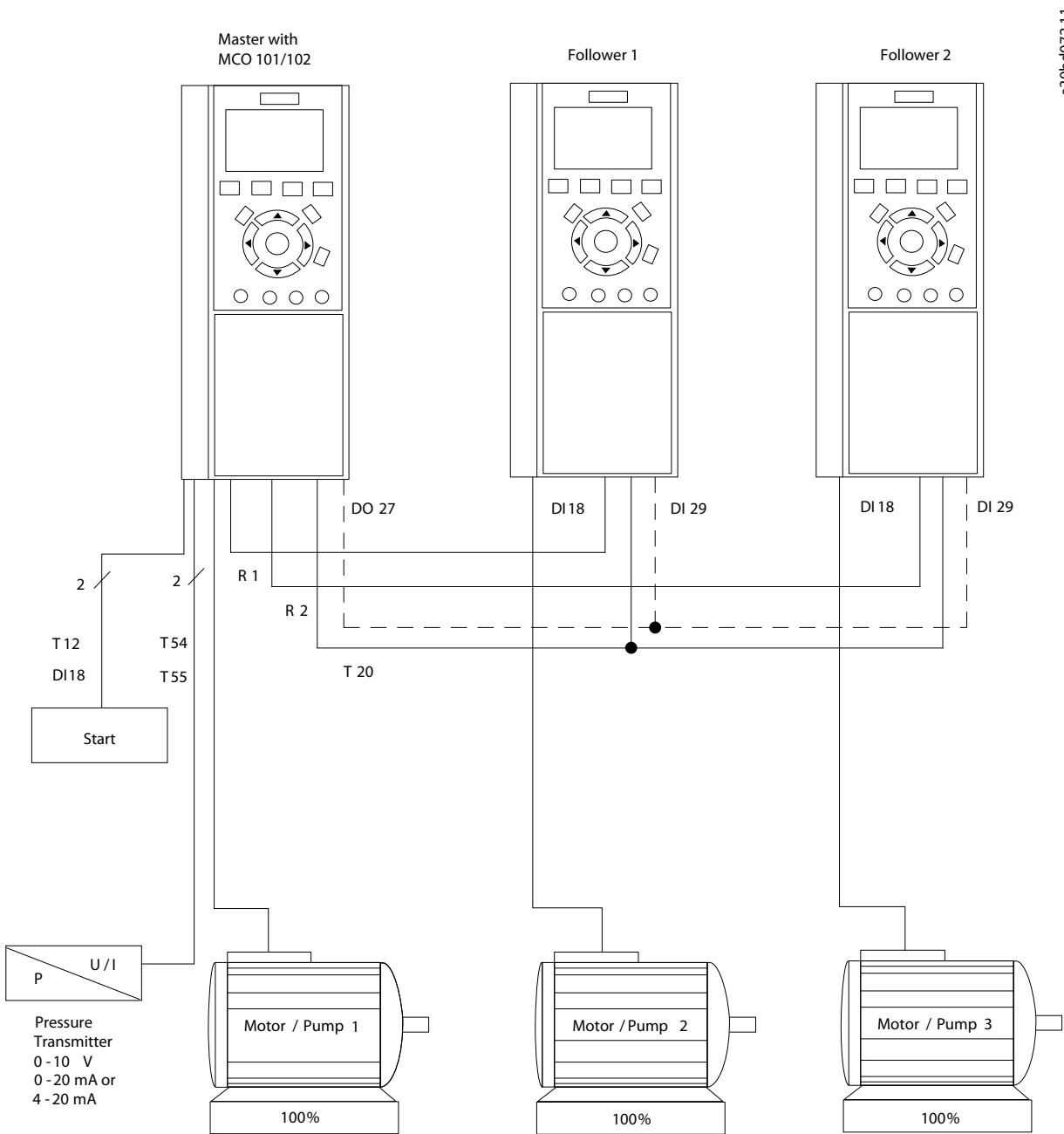
- 27-70.0 Relay 1 → [73] Pump 2 to mains
- 27-70.1 Relay 2 → [74] Pump 3 to mains
- 27-70.9 Relay 10 → [75] Pump 4 to mains
- 27-70.10 Relay 11 → [0] Standard relay
- 27-70.11 Relay 12 → [0] Standard relay

NOTICE

Pressure fluctuations during staging/destaging transitions may occur and it may be less energy-efficient than the master/follower configurations.

3.2.2 Hardware Configuration for Master/Follower Cascade Control

The master/follower cascade control mode offers the best performance, the most precise control, and maximum energy savings. It controls multiple equally sized pumps in parallel, running all pumps at the same speed, and stages the pumps on and off according to system requirements. Compared to traditional cascade control, the number of running pumps is controlled by speed instead of feedback. To obtain the highest energy saving, staging speed on and off must be set correctly according to the system. In this example, terminal 27 of the master drive is used as pulse output for the reference, and terminals 29 of the follower drives are used as pulse input for this reference. While the master drive is running in closed loop, the follower drives are running in open loop. All follower drives are connected to mains and motor in the same way as the master drive.



e30bd072.11

Illustration 4: Basic Wiring Principle for a Master/Follower Configuration (Example)

In this configuration, each pump is controlled by a drive. All pumps and drives must be of the same size. Staging and destaging decisions are made based on the speed of the drive. The constant pressure is controlled by the master drive operating in closed loop. The speed is the same in all running pumps.

In the master/follower mode, VLT® Extended Cascade Controller MCO 101 supports up to 6 pumps, while VLT® Advanced Cascade Controller MCO 102 supports up to 8 pumps.

Configuring as in [Illustration 4](#) requires the following settings in *parameter group 27-7* Connections*:

- 27-70.0 Relay 1 → [1] Drive 2 enable
- 27-70.1 Relay 2 → [2] Drive 3 enable
- 27-70.9 Relay 10 → [0] Standard relay
- 27-70.10 Relay 11 → [0] Standard relay
- 27-70.11 Relay 12 → [0] Standard relay

The system run-time balances all pumps automatically depending on the pump prioritization made in *parameter 27-16 Runtime Balancing*. The master/follower system provides a certain level of redundancy. If the master drive trips, it continues to control the follower drives.

NOTICE

VLT® 24 V DC Supply MCB 107 can be added to increase the level of system redundancy.

Relays set to [0] Std. Relay can be used as general purpose relay controlled by *parameter group 5-4* Relays*.

3.2.3 Hardware Configuration for Mixed Pumps

This configuration combines some of the benefits of the master/follower configuration with some of the initial cost savings of the fixed-speed configurations. It is a good choice when the extra capacity of the fixed pumps is rarely needed.

The mixed-pump configuration supports a mix of variable-speed pumps connected to drives and also some fixed-speed pumps. First, the variable-speed pumps are staged and destaged based on the drive speed. The fixed-speed pumps are staged and destaged last based on the feedback pressure.

NOTICE

The variable-speed pumps and the drives must be of the same size. Fixed-speed pumps may be of different size.

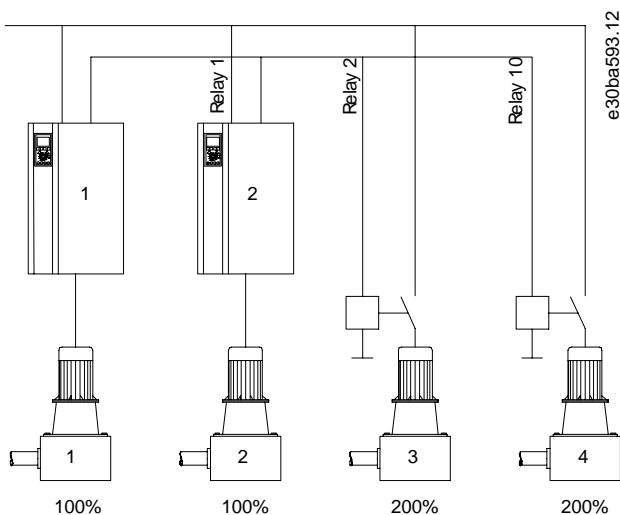


Illustration 5: Mixed-pump Configuration Example

For this configuration, set the relays as follows in *parameter group 27-7* Connections*:

- 27-70.0 Relay 1 → [1] Drive 2 enable
- 27-70.1 Relay 2 → [74] Pump 3 to mains
- 27-70.9 Relay 10 → [75] Pump 4 to mains

- 27-70.10 Relay 11 → [0] Standard relay
- 27-70.11 Relay 12 → [0] Standard relay

3.2.3.1 Unequal-sized Pumps Configuration

The unequal-sized pumps configuration supports a limited mix of fixed-speed pumps in different sizes. It provides for the largest range of system output with the smallest number of pumps.

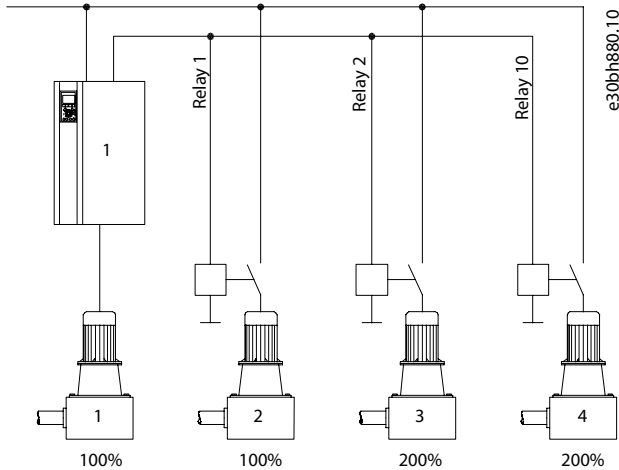


Illustration 6: Example of a Configuration with Unequal-sized Pumps

For this configuration, set the relays as follows in *parameter group 27-7* Connections*:

- 27-70.0 Relay 1 → [73] Pump 2 to mains
- 27-70.1 Relay 2 → [74] Pump 3 to mains
- 27-70.9 Relay 10 → [75] Pump 4 to mains
- 27-70.10 Relay 11 → [0] Standard relay
- 27-70.11 Relay 12 → [0] Standard relay

For a configuration to be valid, it must be possible to stage pumps in increments of 100% of the size of the variable-speed pump of the master drive. The variable-speed pump must control the output between the fixed-speed stages, see [Illustration 7](#).

100% is defined as the maximum flow produced by the pump connected to the master drive. The fixed-speed pumps must be multiples of this size.

NOTICE

Other valid configurations than the ones shown in [Table 3](#) are possible.

Table 3: Valid Configurations

Variable speed	Fixed speed
100%	100% + 200% (see Illustration 7)
100%	100% + 200% + 200%
100%	100% + 100% + 300%
100%	100% + 100% + 300% + 300%
100%	100% + 200% + 400%
100% + 100%	200%
100% + 100%	200% + 200%

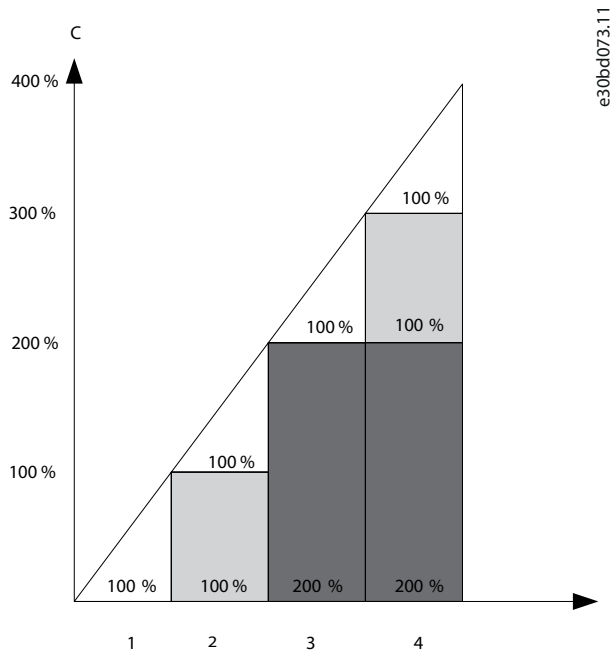


Illustration 7: Example of a Valid Configuration

NOTICE

Invalid configurations, as in [Illustration 8](#), will still run, but will have a poor control performance. This allows only limited operation if a pump fails or is interlocked.

Table 4: Invalid Configurations

Variable speed	Fixed speed	
100%	200%	No control between 100% and 200%
100%	100% + 300%	No control between 200% and 300%, see Illustration 8
100%	100% + 200% + 600%	No control between 400% and 600%

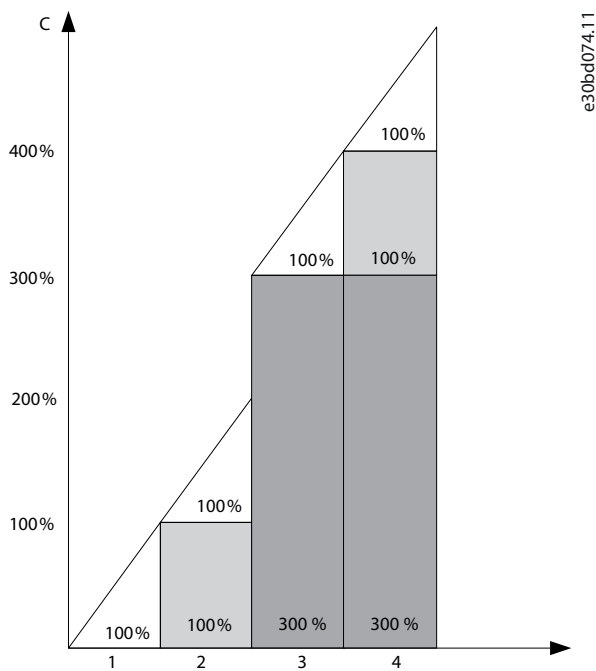


Illustration 8: Example of an Invalid Configuration

3.2.3.2 Mixed-pump Configuration with Alternation

In this configuration, the drive alternates between 2 pumps and controls the other as extra fixed-speed pumps. The Cascade Controller attempts to balance the running hours of the pumps.

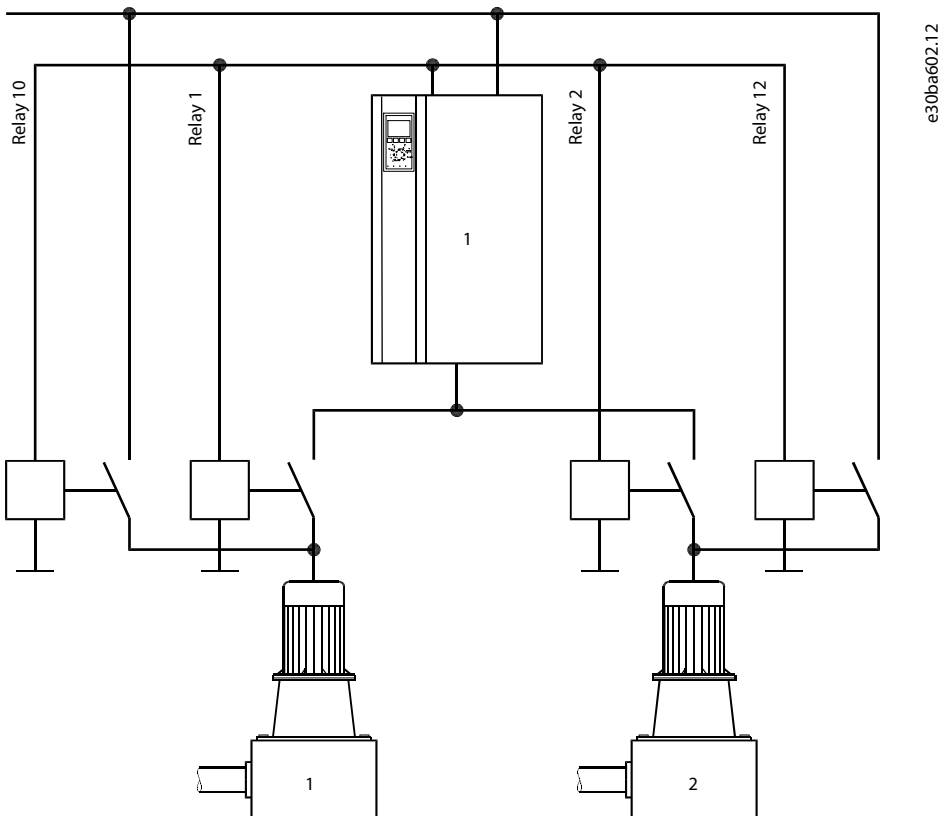


Illustration 9: Example 1

In [Illustration 9](#), the 2 pumps are operated either as variable-speed pumps or as fixed-speed pumps.

For this configuration, set the relay selection as follows in *parameter group 27-7* Connections*:

- 27-70.0 Relay 1 → [8] Pump 1 to drive 1
- 27-70.1 Relay 2 → [16] Pump 2 to drive 1
- 27-70.9 Relay 10 → [72] Pump 1 to mains
- 27-70.10 Relay 11 → [73] Pumps 2 to mains
- 27-70.11 Relay 12 → [0] Standard relay

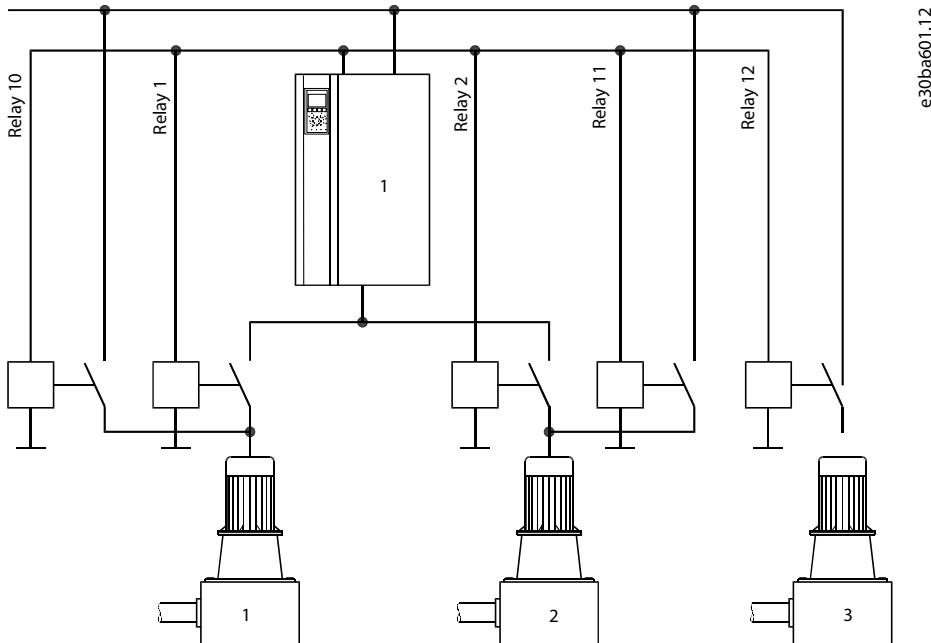


Illustration 10: Example 2

In [Illustration 10](#), 2 pumps are operated either as variable-speed pumps or as fixed-speed pumps. The 3rd pump is an extra fixed-speed pump.

For this configuration, set the relays as follows in *parameter group 27-7* Connections*:

- 27-70.0 Relay 1 → [8] Pump1 to drive 1
- 27-70.1 Relay 2 → [16] Pump2 to drive 1
- 27-70.9 Relay 10 → [72] Pump 1 to mains
- 27-70.10 Relay 11 → [73] Pump 2 to mains
- 27-70.11 Relay 12 → [74] Pump 3 to mains

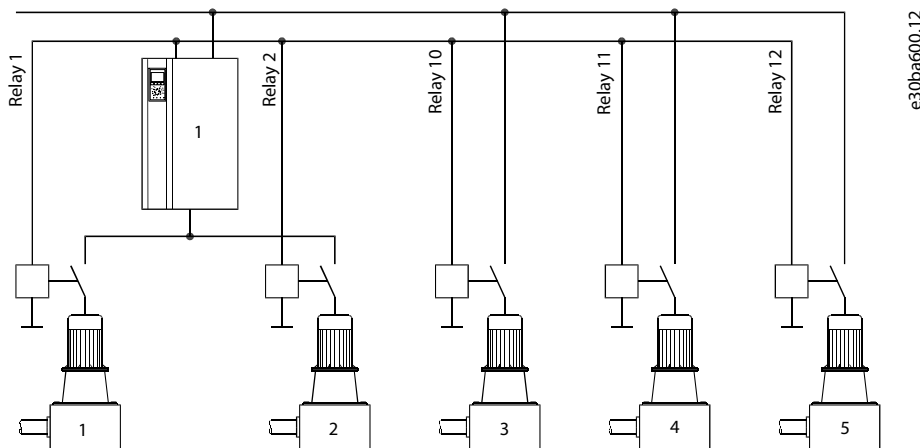


Illustration 11: Example 3

In [Illustration 11](#), either pump 1 or pump 2 is connected to the drive. The pump for the connection to the drive can be selected either automatically for balancing the running hours or forced by the configured alternation event. The fixed-speed pumps 3, 4, and 5 are turned on and off as required.

For this configuration, set the relay as follows in *parameter group 27-7* Connections*:

- 27-70.0 Relay 1 → [8] Pump 1 to drive 1
- 27-70.1 Relay 2 → [16] Pump 2 to drive 1
- 27-70.9 Relay 10 → [74] Pump 3 to mains
- 27-70.10 Relay 11 → [75] Pump 4 to mains
- 27-70.11 Relay 12 → [76] Pump 5 to mains

3.2.4 Using Soft Starters for Fixed-speed Pumps

Soft starters can be used instead of contactors for any configuration using fixed-speed pumps.

NOTICE

Mixing soft starters and contactors prevents control of output pressure during staging and destaging transitions. The use of soft starters delays the staging due to the ramp time of the fixed-speed pump.

3.3 Sleep Mode

If the load on the multi-pump system allows it, it can be stopped by activating the sleep mode function. When in sleep mode, certain configurable conditions are monitored to find out when load has been applied again and the system has to be restarted.

Depending on the system, sleep mode can be activated either from the low-power detection/low-speed detection or via an external signal applied to 1 of the digital inputs (must be programmed via *parameter group 5-1* Digital Inputs*). Using, for example, an electro-mechanical flow switch to detect a no-flow condition, activates sleep mode at the raising edge of the external signal applied.

Implementation and configuration of sleep mode depend on the hardware configuration and the requirements.

3.3.1 Basic Cascade Controller

For Basic Cascade Controller applications, sleep mode can be used and configured exactly as it is described for single-pump applications in the parameter groups 22-2* to 22-4* in the VLT® AQUA Drive FC 202 Programming Guide.

Low-speed detection and low-power detection combined with the timers for minimum run-time, minimum sleep time, and the boost feature are supported. The feedback from the pressure transducer is monitored and when this pressure has dropped with a set percentage below the normal setpoint for pressure (*parameter 22-44 Wake-up Ref./FB Difference*), the motor ramps up again, and pressure is controlled for reaching the set value.

3.3.2 Master/Follower and Mixed-pump Configurations

In multiple-drive applications, sleep mode can be used in 2 different ways:

- Low-speed detection for applications with multiple drives can be enabled by a selection in *parameter 22-22 Low Speed Detection*.
- Using the Stage Off-speeds in *parameter group 27-3* Staging Speed*.

In the following example, sleep mode is entered at 30 Hz in a master/follower application.

	Stage ON [Hz]	Stage OFF [Hz]
Stage 1	48.5 (parameter 2732.1)	30 (parameter 2734.1)
Stage 2	48.5 (parameter 2732.2)	40 (parameter 2734.2)
Stage 3	48.5 (parameter 2732.3)	42 (parameter 2734.3)

This mode is activated by programming the corresponding speed in *parameter 27-33 Stage Off Speed [RPM]* or *parameter 27-34 Stage Off Speed [Hz]*.

The value for this speed has to be higher than the minimum speed in *parameter 4-11 Motor Speed Low Limit [RPM]* or *parameter 4-12 Motor Speed Low Limit [Hz]*.

The value for the override limit in *parameter 27-21 Override Limit* causes the drive to wake up again. The value is entered as a % of the maximum reference as programmed in *parameter 3-03 Maximum Reference*.

3.3.3 Temporary Boost of the Setpoint Before Sleep Mode

In some applications, it can be difficult to detect the no-flow conditions in a reliable way with a fixed setpoint. This may be the case in applications with varying inlet pressure or if the closure of a non-return valve causes a pressure loss.

In these cases, a temporary boost of the setpoint can force the PID to reduce speed. See *parameter 22-22 Low Speed Detection* in the VLT® AQUA Drive FC 202 Programming Guide for further details.

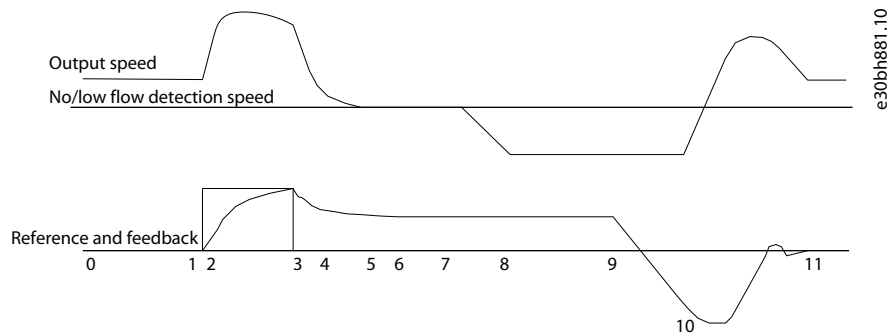


Illustration 12: Temporary Boost of Setpoint

0	System is going into a no-flow condition	6	PID, bring output frequency to minimum speed due to $FB > Ref$
1	Conditions for pulse are present	7	Delay time for no-flow has expired. Sleep mode
2	Pulse equals boost	8	Drive stop, sleep
3	Boost setpoint is reached	9	Load return to system
4	Pressure loss due to back-flow to close no-return valve	10	Conditions for wake-up are present
5	No-return valve is closed and there is no load	11	System running normally

4 Installation

4.1 Before Start

⚠ WARNING ⚠

Never install an option card in a drive during operation.

- Interrupt the power supply to the drive before starting the installation. Note that high voltage may be present, even when the warning LED display lights are off.

Table 5: Discharge Time

Voltage [V]	Minimum waiting time (minutes)					
	4	7	15	20	30	40
200–240	0.25–3.7 kW (0.34–5 hp)	–	5.5–45 kW (7.5–60 hp)	–	–	–
380–480	0.37–7.5 kW (0.5–10 hp)	–	11–90 kW (15–125 hp)	110–250 kW (150–335 hp)	–	315–1500 kW (425–2000 hp)
525–600	0.75–7.5 kW (1.0–10 hp)	–	11–90 kW (15–125 hp)	–	–	–
525–690	–	1.1–7.5 kW (1.5–10 hp)	11–90 kW (15–125 hp)	45–400 kW (60–540 kW)	450–1200 kW (600–1600 hp)	1400 kW (1875 hp)

4.2 VLT® Extended Cascade Controller MCO 101

4.2.1 Installing the VLT® Extended Cascade Controller MCO 101

The VLT® Extended Cascade Control MCO 101 includes 2 changeover contacts and can be fitted into option slot B.

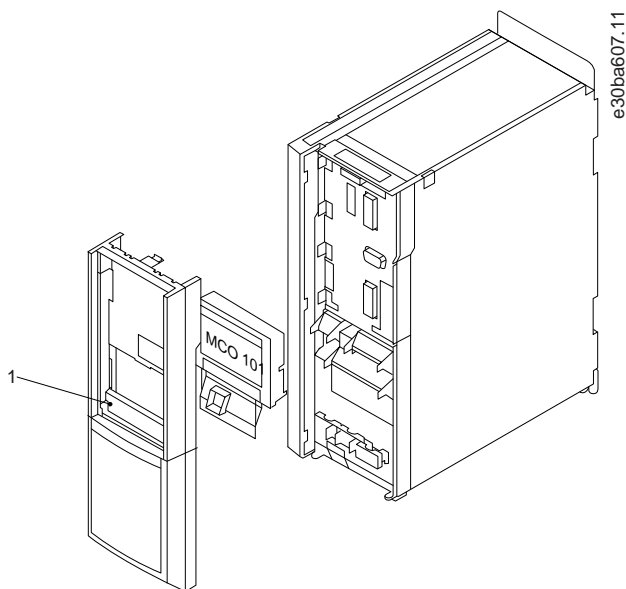
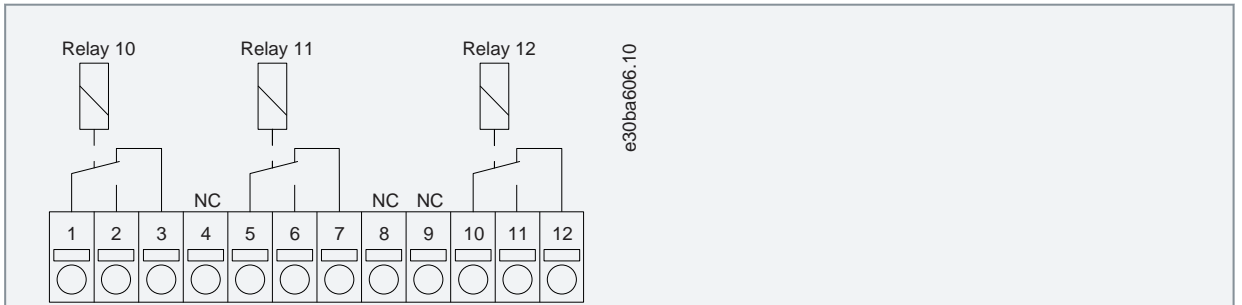


Illustration 13: Mounting of B Options

Procedure

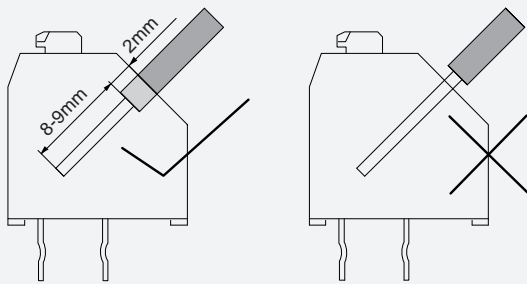
1. Disconnect power to the drive.
2. Disconnect power to the live part connections on the relay terminals.
3. Remove the LCP, the terminal cover, and the cradle from the drive.

4. Fit the MCO 101 option in slot B.
5. Connect the control cables and relieve the cables with the enclosed cable strips.



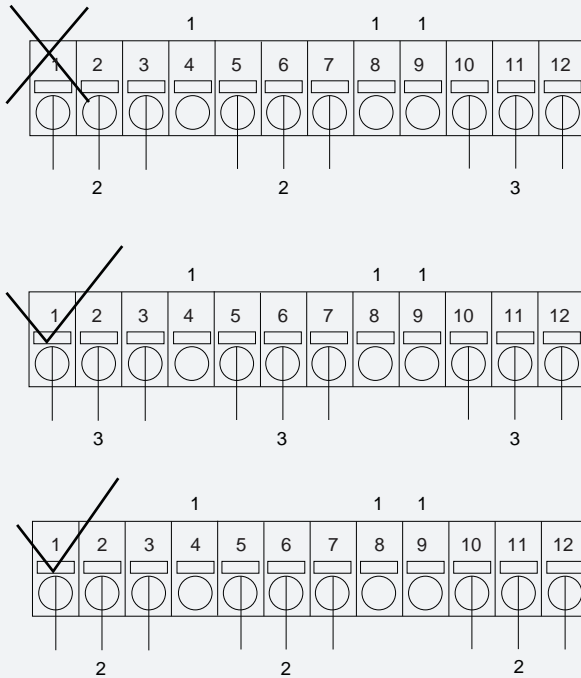
e30ba606.10

Illustration 14: Wiring of Connections



e30ba177.1i

Illustration 15: Mounting of Cables



e30ba176.11

Illustration 16: Incorrect and Correct Relay Wiring

1	NC	3	PELV
2	Live part		

NOTICE

Do not combine low-voltage parts and PELV systems.

6. Fit the extended cradle and terminal cover.
7. Remount the LCP.
8. Connect power to the drive.

4.2.2 Electrical Data, VLT® Extended Cascade Control MCO 101

Maximum terminal load (AC)	240 V AC, 2 A
Maximum terminal load (DC)	24 V DC, 1 A
Minimum terminal load (DC)	5 V, 10 mA
Maximum switching rate at rated load/minimum load	6 min ⁻¹ /20 s ⁻¹

4.3 VLT® Advanced Cascade Controller MCO 102

4.3.1 Installing the VLT® Advanced Cascade Controller MCO 102

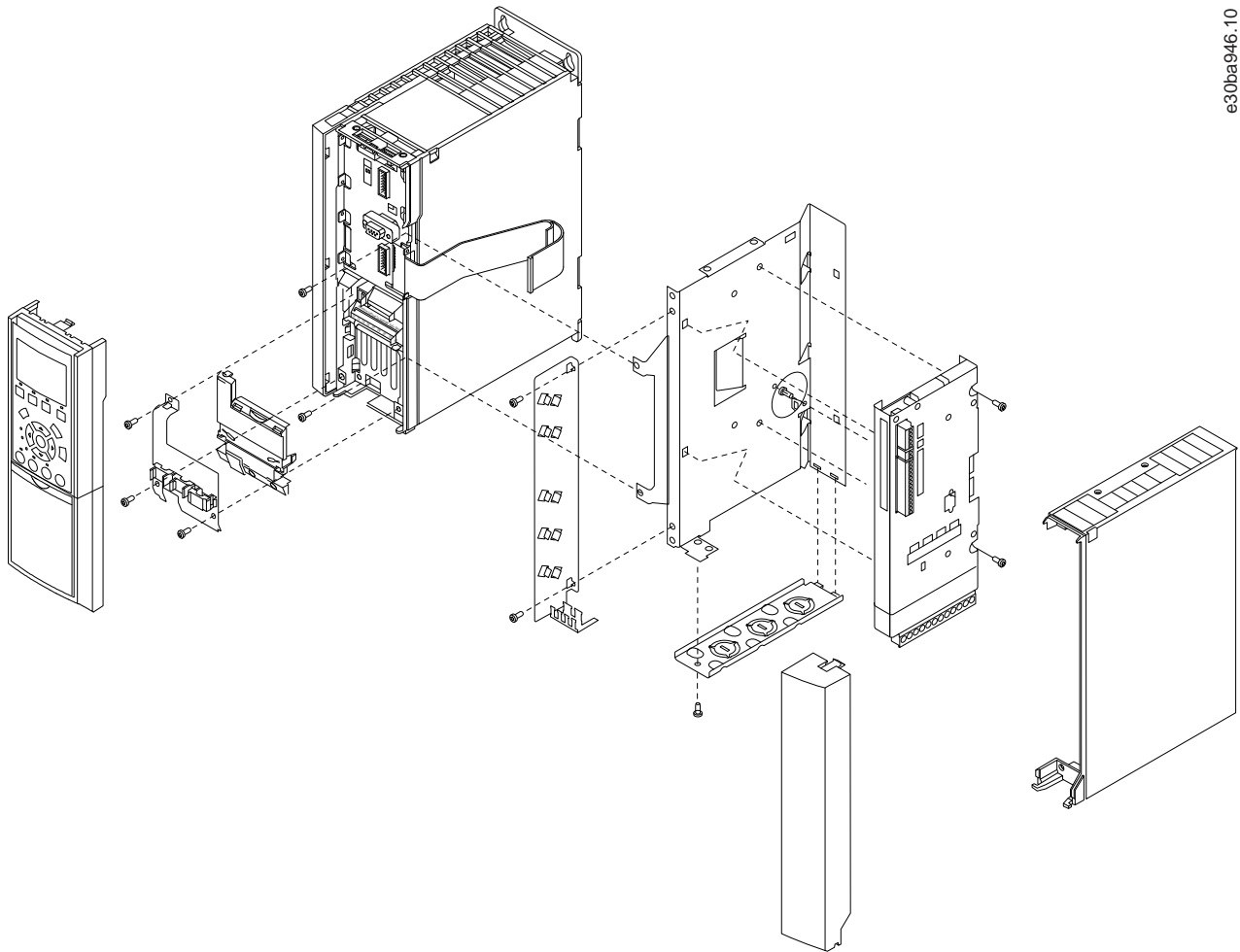
The VLT® Advanced Cascade Controller MCO 102 is exclusively intended for use in option slot C1.

Some items are required for the installation of a C option mounting kit. The items required depend on the drive enclosure.

Table 6: Order Numbers for Mounting Kits and Accessory Bag

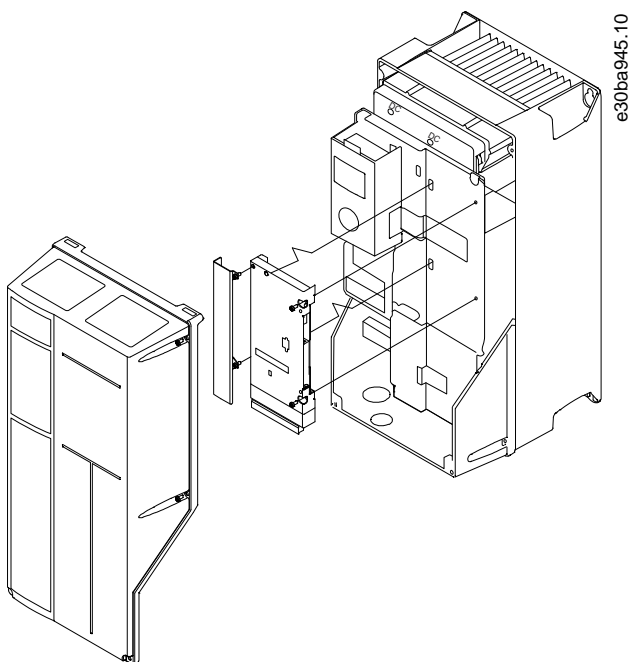
Type	Description	Order number
Options		
MCF 105	Mounting kit, enclosure sizes A2 and A3 (40 mm for 1 C option)	130B7530
MCF 105	Mounting kit, enclosure size A5	130B7532
MCF 105	Mounting kit, enclosure sizes B (except B3), C, D, E, F1, and F3	130B7533
MCF 105	Mounting kit, enclosure size B3 (40 mm for 1 C option)	130B1413
Accessory bag		
MCO 102	Accessory bag	130B0152

A4 does not support C options. If the VLT® Advanced Cascade Controller MCO 102 is needed, select an A5 enclosure.



e30ba946.10

Illustration 17: Enclosure Sizes A2, A3, and B3, 40 mm (only 1 C option)



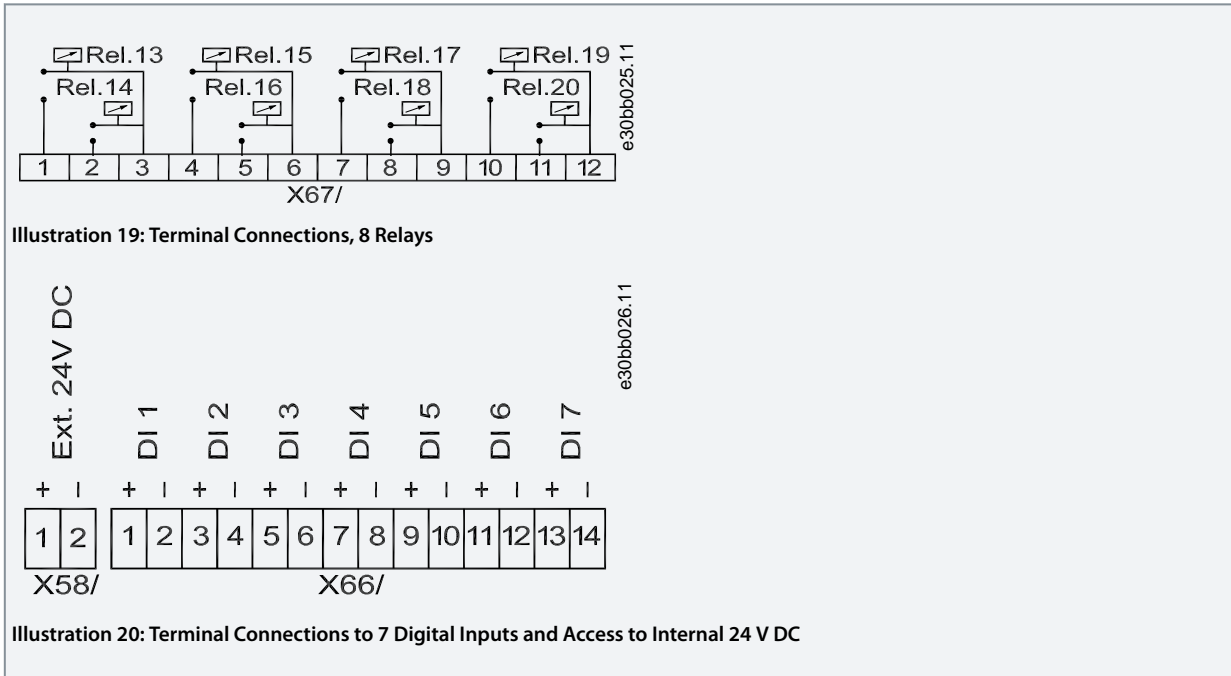
e30ba945.10

Illustration 18: Enclosure Sizes B (except B3) and C

Procedure

1. Disconnect power to the drive.

2. Disconnect power to the live part connections on the relay terminals.
3. Remove the LCP, the terminal cover, and the cradle from the drive.
4. Fit the MCO 102 in slot C1.
5. Connect the control cables and relieve the cables with the enclosed cable strips.



6. Fit the extended cradle and terminal cover.
7. Remount the LCP.
8. Connect power to the drive.

4.3.2 Electrical Data, VLT® Advanced Cascade Control MCO 102

Maximum terminal load (AC)	240 V AC, 2 A
Maximum terminal load (DC)	24 V DC, 1 A
Minimum terminal load (DC)	5 V, 10 mA
Maximum switching rate at rated load/minimum load	6 min ⁻¹ /20 s ⁻¹

5 Configuration of the System

5.1 Configuration of the Extended and Advanced Cascade Controllers

The Extended and Advanced Cascade Controllers, MCO 101 and MCO 102, can be configured quickly using many of the default parameters. For more information about application types and on how to use advanced features of the Cascade Controllers, refer to [3 Applications](#).

N O T I C E

To avoid misconfigurations, check the settings even if the parameters are set to their default values.

5.1.1 Basic Configuration of the Extended and Advanced Cascade Controllers

N O T I C E

Any unused relays are available for other functions via *parameter group 5-4* Relays*.

Procedure

1. Select the values for the parameters in *parameter group 27-1* Configuration*.

Parameter	Description
<i>27-10 Cascade Controller</i>	This parameter is used for enabling or disabling the Extended/Advanced Cascade Controllers. It is also used to extend the number of pumps in Basic Cascade Control applications. In this case, the parameters in <i>Parameter Group 25-** Cascade Controller</i> must be used for the configuration details. The mixed-pump selection is the general selection for the Cascade Controller. If using 1 drive per pump, select the master/follower configuration.
<i>27-11 Number Of Drives</i>	Set the number of drives.
<i>27-12 Number Of Pumps</i>	Set the number of pumps. Default is the number of drives.
<i>Parameter 27-13 Max Number of Pumps Running</i>	This parameter makes it possible to force pumps to stay idle. Example: In a cascade system where 3 pumps are necessary in normal operation, but 4 pumps are installed due to legislation, it is possible to allow only 3 pumps running in parallel to avoid high pressure spikes. Default always equals the number of pumps.
<i>27-14 Pump Capacity</i>	Pump capacity for each pump (indexed parameter). If all pumps are the same size, use the default values. To adjust the setting, select the pump, press [OK], and adjust the capacity.
<i>27-16 Runtime Balancing</i>	Run-time balancing for each pump (indexed parameter). If the system should balance the running hours equally between the pumps, use the default values.
<i>27-17 Motor starters</i>	All fixed-speed pumps must be the same size.
<i>27-18 Spin Time for Unused Pumps</i>	The spin time depends on the size of the pumps.

2. Define the relays in *parameter group 27-7* Connections*.
 - a. Assign 1 relay for each follower drive in the system.
 - b. Assign the relays for the fixed-speed pumps.
 - c. If a single drive is connected to 2 pumps (alternation), configure more relays accordingly.

5.1.2 Configuring Multiple Drives

If more than 1 drive is used with the Cascade Controller, the master drive sets the speed reference for all drives via a digital pulse signal.

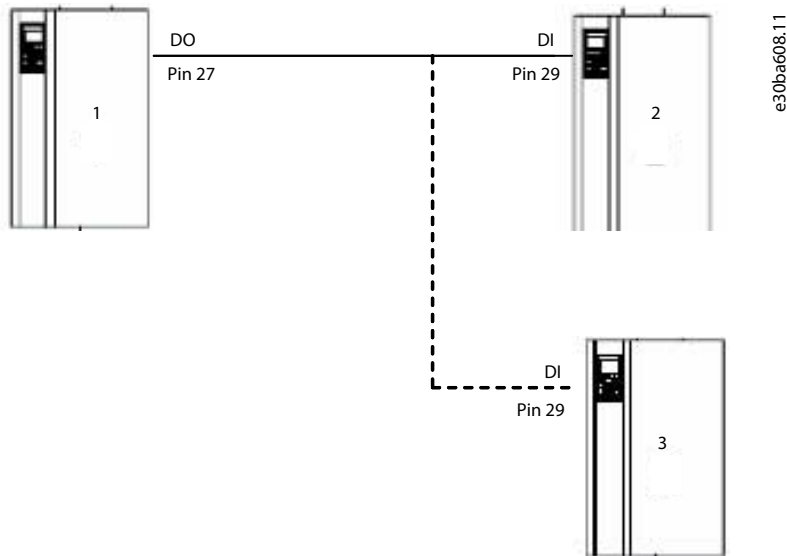


Illustration 21: Multiple Drives Configured for Cascade Control

Procedure

1. Set the basic cascade parameters, see [5.1.1 Basic Configuration of the Extended and Advanced Cascade Controllers](#).
2. Set *parameter 5-01 Terminal 27 Mode* to [1] Output, *parameter 5-30 Terminal 27 Digital Output* to [55] Pulse Output, and *parameter 5-60 Terminal 27 Pulse Output Variable* to [116] Cascade Ref.
3. Set each follower drive to open loop, set *parameter 1-00 Configuration Mode* to [0] Open Loop, *parameter 3-15 Reference 1 Source* to [7] Pulse Input 29, and *parameter 5-13 Terminal 29 Digital Input* to [32] Pulse Input.
4. Set the ramps fast enough to enable the PID controller to maintain control of the system.

NOTICE

Ramp-up times and ramp-down times must be the same for the master drive and for all the follower drives in the system.

5.1.3 Configuring Closed-loop Control

The master drive is the primary controller for the system. It monitors the output pressure, adjusts the speed of the drive, and decides when to add or remove stages.

Procedure

1. Set up the master drive to closed-loop mode with a feedback sensor connected to an analog input of the drive.
2. Set up the PID controller of the master drive to match the requirements of the installation.

For further information on setting up the PID parameters, see the VLT® AQUA Drive FC 202 Programming Guide.

5.1.4 Staging/Destaging of Variable-speed Pumps

Staging occurs when the speed on the drive has reached the value in *parameter 27-31 Stage On Speed [RPM]* (*parameter 27-32 Stage on Speed [Hz]*). At this speed, the system pressure is still maintained, but the pumps start to operate outside of their peak efficiency points. Staging on another pump lowers the speed of all running pumps and provides a more energy-efficient operation.

In master/follower configurations and mixed-pump configurations, the variable-speed pumps are staged and destaged based on the speed of the drives.

Destaging occurs when the speed of the drives drops below the value in *parameter 27-33 Stage Off Speed [RPM]* (*parameter 27-34 Stage Off Speed [Hz]*). At this speed, the system pressure is still maintained, but the pumps are beginning to operate below their peak efficiency points. Destaging a pump causes the speed of the drive to increase into a more energy-efficient range.

Parameter 27-31 Stage On Speed [RPM] (parameter 27-32 Stage On Speed [Hz]) and parameter 27-33 Stage Off Speed [RPM] (parameter 27-34 Stage Off Speed [Hz]) are installation dependent. These parameters are indexed parameters with 1 set of entries for each pump stage.

The stage on and destage off speed can be autotuned during operation or set manually. If Auto tune is enabled, the system starts operation using default settings or the presettings programmed in parameter 27-31 Stage On Speed [RPM] (parameter 27-32 Stage on Speed [Hz]) and parameter 27-33 Stage Off Speed [RPM] (parameter 27-34 Stage Off Speed [Hz]).

The tuning ensures optimum energy efficiency of the system.

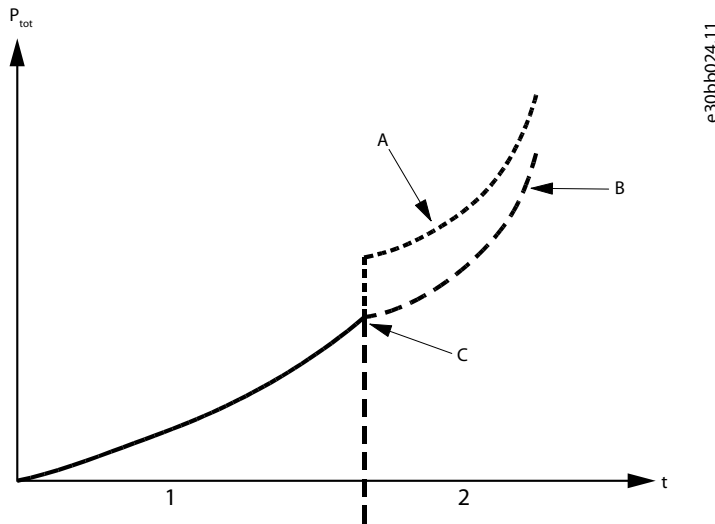


Illustration 22: Optimum Energy Efficiency

1	1 pump running	B	Correct stage on speed adjustment
2	2 pumps running	C	Stage on speed pump 2
A	Incorrect stage on speed adjustment		

During operation, the system monitors the actual energy consumption and optimizes every time a stage or destage takes place.

Parameter	Range	Default
27-30 Auto Tune Staging Speeds	{[0] Disabled, [1] Enabled}	[1] Enabled

5.1.5 Staging/Destaging of Fixed-Speed Pumps

Fixed-speed pumps are staged or destaged based on system pressure.

To avoid turning on and off the pumps too often, define an acceptable range of system pressure along with a period where the pressure is allowed to be outside of this band before staging or destaging occurs. Set the values via:

- Parameter 27-20 Normal Operating Range
- Parameter 27-23 Staging Delay
- Parameter 27-24 Destaging Delay

NOTICE

The parameters are installation dependent.

Stage/destage threshold

The speed of the variable-speed pump at the point of staging or destaging is defined by a stage or destage threshold. These settings prevent overshoot or undershoot in the pressure at staging or destaging.

The optional auto tune of staging and destaging threshold monitors the feedback at the point of staging or destaging and adjusts the settings every time a staging takes place.

Parameter	Range	Default
27-40 Auto Tune Staging Settings	{[0] Disabled, [1] Enabled}	[1] Enabled

5.2 Operation

When the Cascade Controller is enabled, it controls system pressure by varying the speed of the drive and by staging pumps on and off.

The Cascade Controller provides 2 stop functions. One function quickly stops the system. The other function destages the pumps in a sequence, resulting in a pressure-controlled stop. For a VLT® AQUA Drive FC 202 equipped with STO, terminal 37 turns off all relays and coasts the master drive. If any of the digital inputs are set to [8] Start, and the corresponding terminal is used to control start and stop of the drive, setting the terminal to 0 V will turn off all relays and coast the master drive. Pressing [Off] on the LCP causes a sequenced destaging of running pumps.

5.2.1 Checking Pump Status and Controlling Pumps

Select *parameter group 27-0* Control & Status* to check on the status of the Cascade Controller and to control individual pumps. Select a specific pump to view the status, the current running hours, and the total lifetime hours.

Procedure

1. Navigate to *parameter group 27-0* Control & Status*.
2. Press [▲] and [▼] on the LCP to select the pump.
3. Press [▲] and [▼] on the LCP to select the parameter.

5.2.2 Manual Pump Control

Use the Extended/Advanced Cascade Controllers for complete control of each pump in the system, for example for maintenance purposes. Use *parameter 27-02 Manual Pump Control* to control individual pumps through their relays.

This parameter differs from other value-related parameters as selecting 1 of these options causes the action to occur and then the parameter reverts to its default state.

The selections are as follows:

- [0] No Operation - Default value.
- [1] Online - Makes the pump available to the VLT® Extended Cascade Controller MCO 101.
- [2] Alternate On - Forces the selected pump to be the lead pump.
- [3] Offline-Off - Turns off the pump and makes it unavailable for cascading.
- [4] Offline-On - Turns on the pump and makes it unavailable for cascading.
- [5] Offline-Spin - Initiates a pump spin.

If any of the Offline selections are selected, the pump is no longer available to the Cascade Control until Online is selected.

If a pump is taken offline through *parameter 27-02 Manual Pump Control*, the Cascade Controller attempts to compensate for the offline pumps as follows:

- If [3] Offline-Off is selected for a pump that is running, another pump is staged on to compensate for the loss of output.
- If [4] Offline-On is selected for a pump that is off, another pump is staged off to compensate for the excess output.

5.2.3 Run-time Balancing

The Extended/Advanced Cascade Controllers are designed to balance the running hours of the available pumps, but *parameter 27-16 Runtime Balancing* also provides an optional balancing priority for each pump in the system.

Three levels of priority are available:

- [0] Balanced Priority 1
- [1] Balanced Priority 2
- [2] Spare Pump

The Cascade Controller selects a pump to be staged or destaged based on the maximum capacity of the pump (*parameter 27-14 Pump Capacity*), *parameter 27-03 Current Runtime Hours*, and *parameter 27-16 Runtime Balancing*.

During staging, the Cascade Controller balances the current running hours for all pumps set to [0] Balanced Priority 1 in *parameter 27-16 Runtime Balancing*.

If all priority 1 pumps are running, the Cascade Controller balances the pumps set to [1] Balanced Priority 2.

If all priority 1 and 2 pumps are running, pumps set to [2] *Spare Pump* are selected.

During destaging, the reverse occurs. Spare pumps are destaged first, followed by priority 2 pumps, followed by priority 1 pumps. At each priority level, the pump with the highest current run-time hours is destaged first.

N O T I C E

In mixed-pump configurations with more than 1 drive, all variable-speed pumps are staged or destaged before fixed-speed pumps.

Select *parameter 27-19 Reset Current Runtime Hours* to reset the current run-time hours and restart the balancing process. This parameter does not affect the total lifetime hours (*parameter 27-04 Pump Total Lifetime Hours*) for each pump. The total lifetime hours-function is not used for run-time balancing.

5.2.4 Pump Spin for Unused Pumps

If a pump is used only occasionally, the Cascade Controller balances the running hours of the pumps via alternation. If a pump is not used for 72 hours, a pump spin can be triggered.

The spin time can be set in *parameter 27-18 Spin Time for Unused Pumps*. The spin time should be long enough to ensure that the pump stays in good working condition, but short enough not to overpressure the system. To disable the function, set *parameter 27-18 Spin Time for Unused Pumps* to 0.

N O T I C E

The Cascade Controller does not compensate for the extra pressure generated during a pump spin. Keep the spin time as short as possible to prevent damage caused by overpressuring the output.

5.2.5 Total Lifetime Hours

The VLT® Extended Cascade Controller MCO 101 and the VLT® Advanced Cascade Controller MCO 102 track the total lifetime hours for each controlled pump.

Parameter 27-04 Pump Total Lifetime Hours shows a running total of the operating hours for each pump. The total lifetime hours are saved in the non-volatile memory once every hour.

This parameter can also be set to an initial value that reflects the hours of operation for a pump before it was added to the system.

5.2.6 Alternation of the Lead Pump

The Cascade Controller can be configured for lead pump alternation, see also examples in [3.2.3.2 Mixed-pump Configuration with Alternation](#).

In a configuration with multiple drives, the lead pump is defined as the last variable-speed pump running.

In a configuration with only 1 drive, the lead pump is defined as the pump connected to the drive.

During start-up and normal staging/destaging, the Cascade Controller balances the running hours by alternating the lead pump.

Alternation of lead pumps can also be forced manually, for example, via *parameter 27-54 Alternation At Time of Day*, via a digital input, or by alternation time parameters.

5.2.7 Staging/Destaging in Mixed-pump Configurations

Two methods are used to decide when pumps should be staged or destaged:

- Speed of the drives.
- Feedback pressure exceeding the normal operating range.

In a mixed-pump configuration with more than 1 drive, both methods are used. In the following example, feedback is referred to as pressure.

Staging

When the master drive receives a start command, a variable-speed pump is selected and starts using 1 of the available drives.

If the system pressure drops, the speed of the drive increases to meet the demand for more flow. While maintaining the pressure, if the drive exceeds *parameter 27-31 Stage On Speed [RPM]* (or *parameter 27-32 Stage On Speed [Hz]*) and remains above that speed for the time specified in *parameter 27-33 Stage Off Speed [RPM]* (*parameter 27-34 Stage Off Speed [Hz]*), the next variable-speed pump is staged on.

If the Cascade Controller is unable to maintain the system pressure with all variable-speed pumps running at maximum, it stages on fixed-speed pumps. If pressure goes below the setpoint with the percentage set in *parameter 27-20 Normal Operating Range* and stays below the setpoint for the time specified in *parameter 27-23 Staging Delay*, a fixed-speed pump stages on.

Destaging

If the system pressure increases, the speed of the drive decreases. If the drive drops below the values specified in *parameter 27-33 Stage Off Speed [RPM]* (or *parameter 27-32 Stage Off Speed [Hz]*) and stays there for the time specified in *parameter 27-24 Destaging Delay*, a variable-speed pump is staged off.

If the system pressure is still too high with only 1 drive running at minimum speed, it destages fixed-speed pumps. A fixed-speed pump is destaged when the pressure exceeds the setpoint in *parameter 27-20 Normal Operating Range* and stays there for the time specified in *parameter 27-24 Destaging Delay*. If the system demand continues to drop, the system enters sleep mode.

5.2.8 Override Staging/Destaging

Normal staging and destaging handle most of the situations in typical applications. However, when rapid response to changes in system pressure is required, the Cascade Controller is equipped to stage and destage pumps immediately.

Staging

When the system pressure drops below the override limit (*parameter 27-21 Override Limit*), the Cascade Controller immediately stages on a pump to meet the demand.

If the system pressure continues to stay below *parameter 27-21 Override Limit* for the time specified in *parameter 27-25 Override Hold Time*, the Cascade Controller stages on the next pump. This behavior is repeated until all pumps are on or until system pressure drops below the override limit.

Destaging

When the system pressure exceeds *parameter 27-21 Override Limit*, the Cascade Controller immediately destages a pump to reduce the pressure.

If the system pressure continues to stay above the value in *parameter 27-21 Override* for the time specified in *parameter 27-25 Override Hold Time*, the Cascade Controller destages another pump. This behavior is repeated until only the lead pump is left on or until the pressure stabilizes.

Parameter 27-21 Override Limit is set as a % of the maximum reference. It defines a point above and below the system setpoint where override staging and destaging occur.

5.2.9 Minimum Speed Destaging

To reduce energy usage, the Cascade Controller can destage a fixed-speed pump if the lead pump is running at minimum speed for the time set in *parameter 27-27 Min Speed Destage Delay*.

5.2.10 Fixed-speed-only Operation

Fixed-speed-only operation keeps critical systems operating even if all variable-speed pumps are unavailable to the Cascade Controller. In this situation, the Cascade Controller maintains system pressure by turning on and off fixed-speed pumps.

Staging

If all the variable-speed pumps are unavailable and the system pressure drops below the limit in *parameter 27-22 Fixed Speed Only Operating Range* for the time specified in *parameter 27-23 Staging Delay*, a fixed-speed pump is turned on.

Destaging

If all variable-speed pumps are unavailable and the system pressure exceeds the limit set in *parameter 27-22 Fixed Speed Only Operating Range* for the time specified in *parameter 27-24 Destaging Delay*, a fixed-speed pump is turned off.

5.2.11 Flow Compensation for Applications with Cascade Controller

Flow compensation allows placing the pressure sensor close to the drive, even if it is not the place for the wanted pressure setpoint. It adjusts the setpoint automatically according to the pressure drop in the system which depends on the system flow. In Cascade Controller applications, this is done step-wise based on the number of pumps in operation.

It uses the feedback to estimate the setpoint required at various rates of flow. The calculation of the theoretical curve results in step-wise adjusted setpoints following this curve. Setpoint 1 is the minimum pressure required when the system is running with only 1 pump operating and under minimum load conditions. Setpoint 2 is used when all pumps are running.

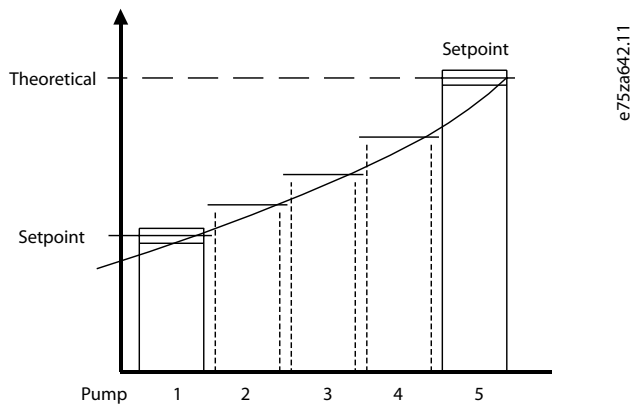


Illustration 23: Calculation of Theoretical Curve

The range of the curve is determined by the no/low flow point and the uncompensated setpoint (for example, in *parameter 20-21 Setpoint 1*).

Besides the configuration of the Cascade Controller, the required programming steps are:

- Enable flow compensation in *parameter 22-80 Flow Compensation*.
- Program the pressure at no-flow speed in *parameter 22-87 Pressure at No-Flow Speed*.
- Program the uncompensated setpoint (for example, in *parameter 20-21 Setpoint 1*).

If the pressure feedback signal originates at the far end of the system, the drive does not need to compensate for system pressure changes due to flow, and the default feedback process can be used.

6 Parameter Descriptions

6.1 Parameter Group 27-**, Cascade CTL Option

N O T I C E

If 1 of the Cascade Controller options is used to extend the number of pumps in a Basic Cascade, use the parameters in *parameter group 25-** Cascade Controller*. See VLT® AQUA Drive FC 202 Programming Guide for further information.

For the following array parameters, the index refers to the number of the (specific) pump. For stage on/stage off speeds, the index reflects the number of pumps in operation.

- *Parameter 27-01 Pump Status*
- *Parameter 27-02 Manual Pump Control*
- *Parameter 27-03 Current Runtime Hours*
- *Parameter 27-04 Pump Total Lifetime Hours*
- *Parameter 27-14 Pump Capacity*
- *Parameter 27-16 Runtime Balancing*
- *Parameter 27-31 Stage On Speed [RPM]*
- *Parameter 27-32 Stage On Speed [Hz]*
- *Parameter 27-33 Stage Off Speed [RPM]*
- *Parameter 27-34 Stage Off Speed [Hz]*

N O T I C E

For *parameter 27-70 Relay*, index 0 refers to relay 1, index 1 refers to relay 2, index 2 refers to relay 3 ... index 19 refers to relay 20.

6.1.1 Parameter Group 27-0*, Control & Status

Control and status parameters are for monitoring and manual control of the pumps.

Press [▲] and [▼] to select a pump. Press [▲] and [▼] to change settings.

Table 7: Parameter 27-01 Pump Status

Option	Function
	<i>Pump Status</i> is a readout parameter showing the status of each pump in the system.
[0] Ready	The pump is available for use by the Cascade Controller.
[1] On Drive	The pump is controlled by the Cascade Controller, the pump is connected to a drive and running.
[2] On Mains	The pump is controlled by the Cascade Controller, the pump is connected to mains and running.
[3] Offline - Off	The pump is not available for use by the Cascade Controller, and the pump is off.
[4] Offline - On Mains	The pump is not available for use by the Cascade Controller, and the pump is connected to mains and running.
[5] Offline - On Drive	The pump is not available for use by the Cascade Controller, and the pump is connected to mains and running.
[6] Offline - Fault	The pump is not available for use by the Cascade Controller, and the pump is connected to mains and running.
[7] Offline - Hand	The pump is not available for use by the Cascade Controller, and the pump is connected to mains and running.
[8] Offline - External Interlock	The pump has been externally interlocked and is off.

Option		Function
[9]	Spinning	The Cascade Controller is executing a spin cycle for the pump.
[10]	No Relay Connection	The pump is not directly connected to a drive, and no relay has been assigned to the pump.

Table 8: Parameter 27-03 Current Runtime Hours

Range		Function
0 h*	[0-2147483647 h]	<i>Current Runtime Hours</i> is a readout parameter showing the total number of hours each pump has been running since the last reset. This time is used to balance the running hours between the pumps. The times may all be reset to 0 via <i>parameter 27-91 Cascade Reference</i> .

Table 9: Parameter 27-04 Pump Total Lifetime Hours

Range		Function
0 h*	[0-2147483647 h]	<div style="text-align: center; background-color: #cccccc; padding: 5px;">NOTICE</div> <p>This parameter may be set individually to any value for maintenance purposes.</p> <p><i>Pump Total Lifetime Hours</i> is the total operating hours for each connected pump.</p>

6.1.2 Parameter Group 27-1*, Configuration

Use the configuration parameters for setting, for example, cascade control mode, number of pumps, number of drives, and pump capacity.

Table 10: Parameter 27-10 Cascade Controller Mode

Option		Function
		<i>Cascade Controller Mode</i> sets the operating mode.
[0]	Disabled	
[1]	Master/Follower	
[2]	Mixed Pumps	
[3]	Basic Cascade Ctrl	

Table 11: Parameter 27-11 Number of Drives

Range		Function
Size related*	[1-8]	Number of drives to be controlled by the Cascade Controller. <ul style="list-style-type: none"> • MCO 101: 1–6 • MCO 102: 1–8

Table 12: Parameter 27-12 Number of Pumps

Range		Function
0*	[0-Number of Drives]	Number of pumps to be controlled by the Cascade Controller. <ul style="list-style-type: none"> • MCO 101: 0–6 • MCO 102: 0–8

Table 13: Parameter 27-13 Max Number of Pumps Running

Range		Function
Parameter 27-12 Number of Pumps*	[1-8]	Limit the maximum number of pumps running simultaneously to prevent overpressure. Default is always equal to <i>parameter 27-12 Number of Pumps</i> . Any change to <i>parameter 27-12 Number of Pumps</i> forces a change to <i>parameter 27-13 Max Number of Pumps Running</i> .

Table 14: Parameter 27-14 Pump Capacity

Range		Function
100%*	[10-800%]	<i>Pump Capacity</i> sets the capacity of each pump in the system relative to the 1 st pump. This is an indexed parameter with 1 entry per pump. The capacity for the 1 st pump is always considered to be 100%.

Table 15: Parameter 27-16 Runtime Balancing

Option	Function
	<i>Runtime Balancing</i> sets the priority of each pump for balancing its running hours. The pumps with the highest priority are operated before the lower-prioritized pumps. Pumps with the same priority are staged/dstaged based on the running hours.
[0] Balanced Priority 1	Turned on first, turned off last.
[1] Balanced Priority 2	Turned on if no priority 1 pumps are available. Turned off before priority 1 pumps are turned off.
[2] Spare Pump	Turned on last, turned off first.

Table 16: Parameter 27-17 Motor Starters

Option	Function
	<i>Motor Starters</i> selects the type of mains starters used on the fixed-speed pumps. All fixed-speed pumps must be configured in the same way.
[0] Direct Online	
[1] Soft Starter	Adds a delay when staging and destaging corresponding to the soft starter ramp time, see <i>parameter 27-41 Ramp Down Delay</i> and <i>parameter 27-42 Ramp Up Delay</i> .
[2] Star/Delta	Adds a delay at staging, controlled by <i>parameter 27-42 Ramp Up Delay</i> .

Table 17: Parameter 27-18 Spin Time for Unused Pumps

Range	Function
Size related*	[0-99 s]
<p>NOTICE</p> <p>Setting this parameter too high may cause overpressure to some systems.</p>	
	<i>Spin Time for Unused Pumps</i> sets the length of time to spin unused pumps. If a fixed-speed pump has not been run in the last 72 hours, it is turned on for the time set in this parameter. This is to prevent damage caused by leaving the pump off too long. The spin feature may be disabled by setting the value of this parameter to 0.

Table 18: Parameter 27-19 Reset Current Runtime Hours

Option	Function
	<i>Reset Current Runtime Hours</i> is used for resetting all current runtime hours to 0. This time is used for runtime balancing.

Option		Function
[0]	Do not reset	
[1]	Do reset	

6.1.3 Parameter Group 27-2*, Bandwidth Settings

Parameters for configuring control response.

Table 19: Parameter 27-20 Normal Operating Range

Range		Function
Size related*	[1-100%]	<i>Normal Operating Range</i> is the allowed offset from the setpoint before a pump may be added or removed. The system must be outside this limit for the time specified in <i>parameter 27-23 Staging Delay</i> or in <i>parameter 27-24 Destaging Delay</i> before a cascade operation takes place. Normal refers to the system operating with at least 1 variable-speed pump available. This value is entered as a % of maximum reference, see <i>parameter 21-12 Ext. 1 Maximum Reference</i> in the VLT® AQUA Drive FC 202 Programming Guide for further information.

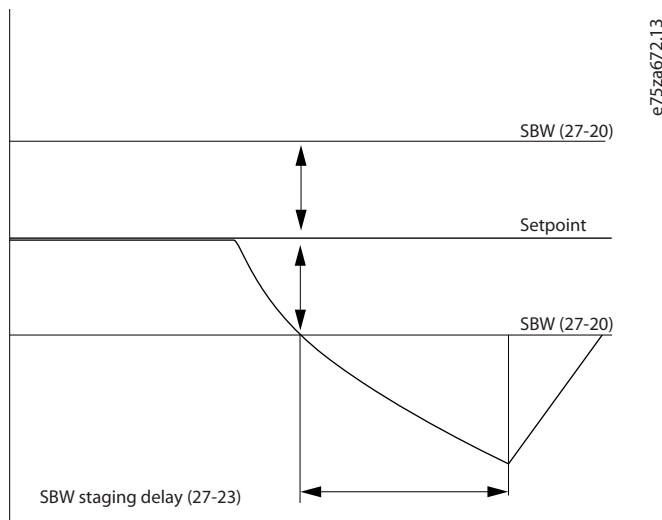


Illustration 24: SBW Staging Delay

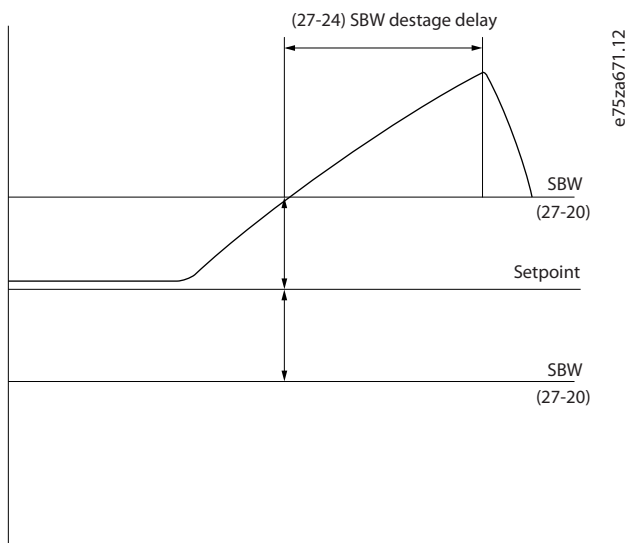


Illustration 25: SBW Destage Delay

Table 20: Parameter 27-21 Override Limit

Range	Function
100%* [1-100%]	<p><i>Override Limit</i> is the allowed offset from the setpoint before a pump immediately is added or removed (for example, if a fire tab is turned on). Normal operating range includes a delay that limits the system response to transients. This makes the system respond too slowly to large demand changes. The override limit causes the drive to respond immediately. The value is entered as a % of maximum reference (<i>parameter 21-12 Ext. 1 Maximum Reference</i>). Override operation may be disabled by setting this parameter to 100%.</p> <div style="text-align: center; background-color: #cccccc; padding: 5px;">NOTICE</div> <p>In master/follower applications, the override limit is used as wake-up condition.</p>

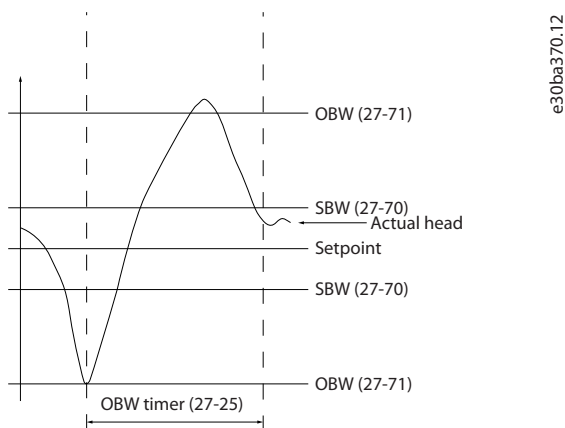


Illustration 26: Override Bandwidth

Table 21: Parameter 27-22 Fixed Speed Only Operating Range

Range	Function
Size related* [0- Par 27-21 %]	<p><i>Fixed Speed Only Operating Range</i> is the allowed offset from the setpoint before a pump may be added or removed when there are no operational variable-speed pumps. The system must be outside this limit for the time specified in <i>parameter 27-23 Staging Delay</i> or <i>parameter 27-24 Destaging Delay</i> before a cascade operation may take place. The value is entered as a % of maximum reference. When there are no operational variable-speed pumps, the system tries to maintain control with the remaining fixed-speed pumps.</p>

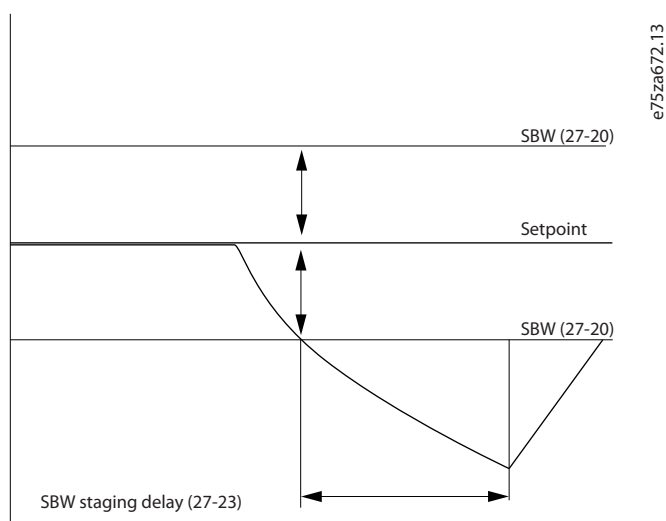


Illustration 27: SBW Staging Delay

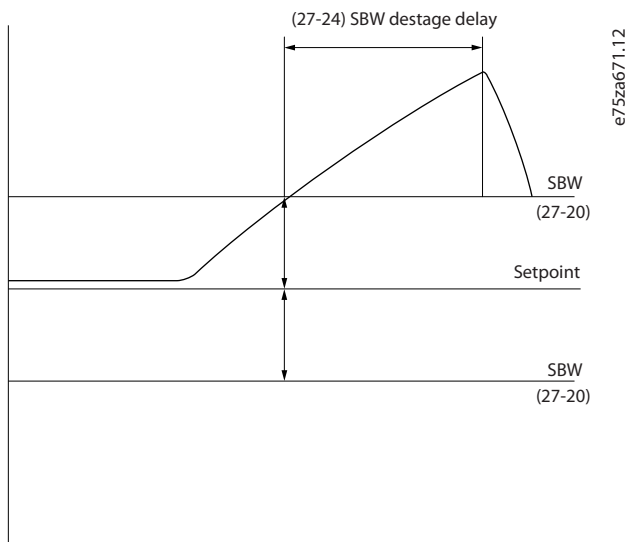


Illustration 28: SBW Destage Delay

Table 22: Parameter 27-23 Staging Delay

Range	Function
15 s* [0-3000 s]	<i>Staging Delay</i> is the time that the system feedback must remain below the operating range before a pump may be turned on. If the system is operating with at least 1 variable-speed pump available, <i>parameter 27-20 Normal Operating Range</i> is used. If there are no variable-speed pumps available, <i>parameter 27-22 Fixed Speed Only Operating Range</i> is used.

Table 23: Parameter 27-24 Destaging Delay

Range	Function
15 s* [0-3000 s]	<i>Destaging Delay</i> is the time that the system feedback must remain above the operating range before a pump may be turned off. If the system is operating with at least 1 variable-speed pump available, <i>parameter 27-20 Normal Operating Range</i> is used. If there are no variable-speed pumps available, <i>parameter 27-22 Fixed Speed Only Operating Range</i> is used.

Table 24: Parameter 27-25 Override Hold Time

Range	Function
10 s* [0-300 s]	<i>Override Hold Time</i> is the minimum time that must elapse after a stage or destage before a stage or destage may take place due to the system exceeding the override limit (<i>parameter 27-21 Override Limit</i>). The override hold time is designed to allow the system to stabilize after a pump is turned on or off. If this delay is not long enough, the transients caused by turning a pump on or off may cause the system to add or remove another pump when it should not.

Table 25: Parameter 27-27 Min-Speed Destage Delay

Range	Function
15 s* [0-300 s]	<i>Min-Speed Destage Delay</i> is the time that the lead pump must be running at minimum speed while the system feedback is still inside the normal operating band before a pump is turned off to save energy. Energy savings may be realized by turning off a pump if the variable-speed pumps are operating at minimum speed but the feedback is still in band. Under these conditions, a pump may be turned off and the system is still able to maintain control. The pumps that remain on will then be operating more efficiently.

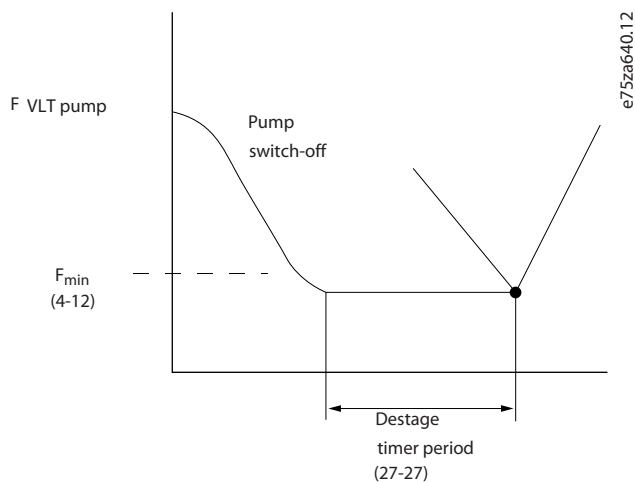


Illustration 29: Destage Timer Period

6.1.4 Parameter Group 27-3*, Staging Speed

Use these parameters for configuring master/follower control response.

Table 26: Parameter 27-30 Auto Tune Staging Speeds

Option	Function
[0]	Disabled
[1]	Enabled <i>Parameters 27-31 to 27-34 are kept up-to-date with new automatically calculated values. If parameters 27-31 to 37-34 are modified from the bus or LCP, the new values are used but continue to be tuned automatically. Values are recalculated and the parameters are updated when staging occurs.</i>

Table 27: Parameter 27-31 Stage On Speed [RPM]

Range	Function
Size related* [0-par. 4-13 RPM]	To be used if RPM is selected. If the lead pump is operating above stage on speed for the time specified in <i>parameter 27-23 Staging Delay</i> and a variable-speed pump is available, it is turned on.

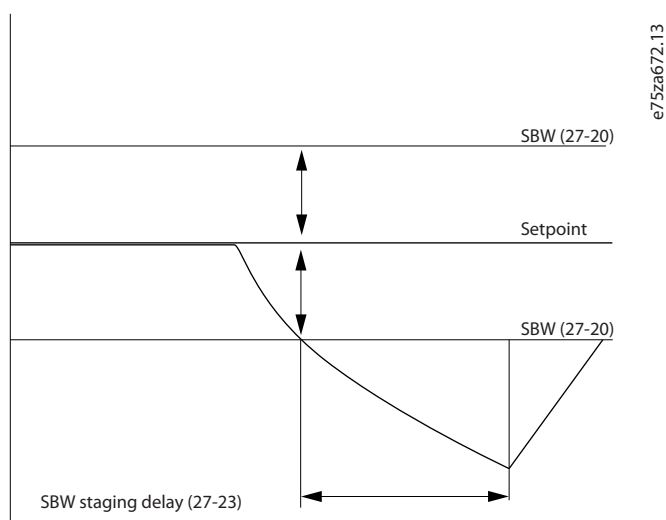


Illustration 30: SBW Staging Delay

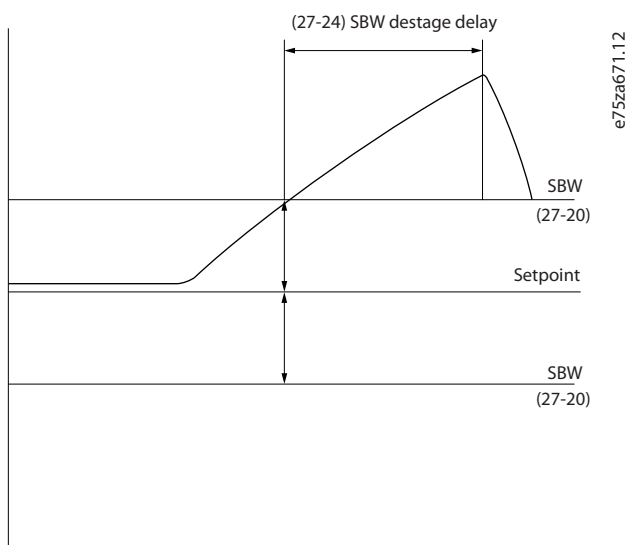


Illustration 31: SBW Destage Delay

Table 28: Parameter 27-32 Stage On Speed [Hz]

Range		Function
Size related*	[0-par. 4-14 Hz]	To be used if Hz is selected. If the lead pump is operating above stage on speed for the time specified in <i>parameter 27-23 Staging Delay</i> and a variable-speed pump is available, it is turned on.

Table 29: Parameter 27-33 Stage Off Speed [RPM]

Range		Function
Size related*	[0-1500 RPM]	If the lead pump operates below stage off speed for the time specified in <i>parameter 27-24 Destaging Delay</i> and more than 1 variable-speed pump is on, another variable-speed pump is turned off.

Table 30: Parameter 27-34 Stage Off Speed [Hz]

Range		Function
Size related*	[0-50 Hz]	If the lead pump operates below stage off speed for the time specified in <i>parameter 27-24 Destaging Delay</i> and more than 1 variable-speed pump is on, another variable-speed pump is turned off.

6.1.5 Parameter Group 27-4*, Staging Settings

Use these parameters for configuring staging transitions.

Table 31: Parameter 27-40 Auto Tune Staging Settings

Option	Function
[0] Disabled	Staging or destaging threshold.
[1] Enabled	Staging and destaging threshold are auto tuned during operation. The auto tuning optimizes the settings and thereby prevents pressure overshoot and undershoot when staging and destaging.

Table 32: Parameter 27-41 Ramp Down Delay

Range		Function
10 s*	[0-120 s]	<i>Ramp Down Delay</i> sets the delay between turning on a soft starter-controlled pump and ramping down a drive-controlled pump. This is only used for soft starter and star/delta-controlled pumps.

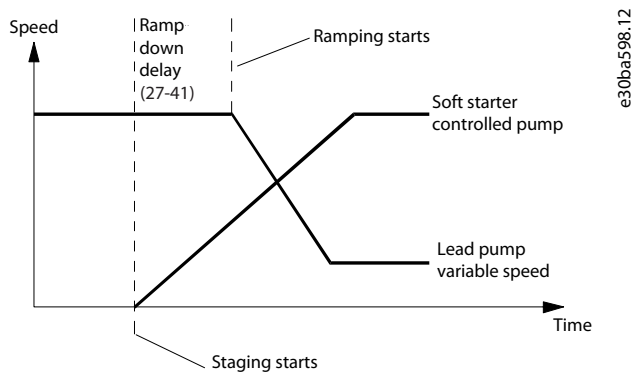


Illustration 32: Ramp-down Delay

Table 33: Parameter 27-42 Ramp Up Delay

Range	Function
2 s* [0-12 s]	Sets the delay between turning off a soft starter-controlled pump and ramping up the drive-controlled pump. This is only used for soft starter-controlled pumps.
<p>NOTICE</p> <p>Not used with star/delta-controlled pumps.</p>	

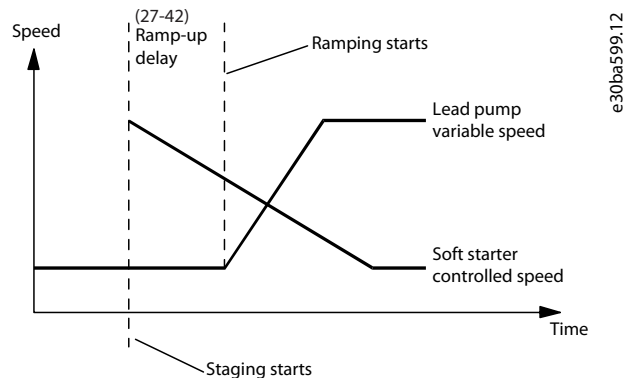


Illustration 33: Ramp-up Delay

Table 34: Parameter 27-43 Staging Threshold

Range	Function
Size related* [0-100%]	Staging threshold is the speed in the staging ramp at which the fixed-speed pump should be turned on. Set as a percentage of the maximum pump speed. If <i>parameter 27-40 Auto Tune Staging Settings</i> is [1] Enabled, <i>parameter 27-43 Staging Threshold</i> and <i>parameter 27-44 Destaging Threshold</i> are kept up-to-date with new automatically calculated values. If <i>parameter 27-43 Staging Threshold</i> and <i>parameter 27-44 Destaging Threshold</i> are modified from the bus or LCP, the new values are used but continue to be tuned automatically.

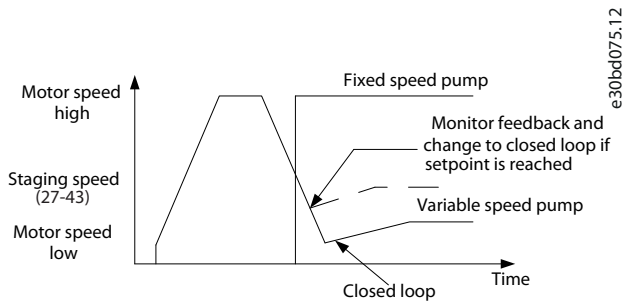


Illustration 34: Staging Speed, Master/follower Configuration

Table 35: Parameter 27-44 Destaging Threshold

Range	Function
Size related* [0-100%]	Destaging threshold is the speed in the staging ramp at which the fixed-speed pump should be turned on. Set as a percentage of the maximum pump speed. If <i>parameter 27-40 Auto Tune Staging Settings</i> is [1] Enabled, <i>parameter 27-43 Staging Threshold</i> and <i>parameter 27-44 Destaging Threshold</i> are kept up-to-date with new automatically calculated values. If <i>parameter 27-43 Staging Threshold</i> and <i>parameter 27-44 Destaging Threshold</i> are modified from the bus or LCP, the new values are used but continue to be tuned automatically.

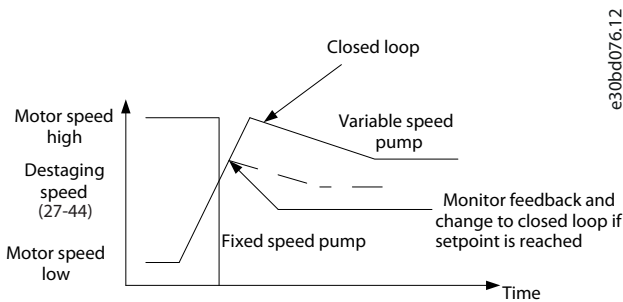


Illustration 35: Destaging Speed, Master/follower Configuration

Table 36: Parameter 27-45 Staging Speed [RPM]

Range	Function
0 RPM* [0-0 RPM]	<i>Staging Speed</i> is a readout parameter that shows the actual staging speed based on the staging threshold.

Table 37: Parameter 27-46 Staging Speed [Hz]

Range	Function
0 Hz* [0-0 Hz]	<i>Staging Speed</i> is a readout parameter that shows the actual staging speed based on the staging threshold.

Table 38: Parameter 27-47 Destaging Speed [RPM]

Range	Function
0 RPM* [0-0 RPM]	<i>Destaging Speed</i> is a readout parameter that shows the actual staging speed based on the destaging threshold.

Table 39: Parameter 27-48 Destaging Speed [Hz]

Range	Function
0 Hz* [0-0 Hz]	<i>Destaging Speed</i> is a readout parameter that shows the actual staging speed based on the destaging threshold.

Table 40: Parameter 27-49 Staging Principle

Option		Function
		Select the staging principle for the staging of fixed-speed pumps (direct online mode).
[0]*	Normal	
[1]	Rapid Staging	The drive returns to closed-loop operation immediately after a pump was staged or destaged. Use this setting in systems with rapid demand changes.

6.1.6 Parameter Group 27-5*, Alternation Settings

Use these parameters for configuring alternations.

Table 41: Parameter 27-51 Alternation Event

Option		Function
[0]	Off	
[1]	At destage	

Table 42: Parameter 27-52 Alternation Time Interval

Range		Function
0 min*	[0-10080 min]	Use this parameter for setting the time between alternations. Disable the function by setting the parameter to 0. To see the time remaining until the next alternation occurs, check <i>parameter 27-53 Alternation Timer Value</i> .

Table 43: Parameter 27-53 Alternation Timer Value

Range		Function
0 min*	[0-10080 min]	<i>Alternation Timer Value</i> is a readout parameter that shows the time remaining before an interval-based alternation takes places. <i>Parameter 27-52 Alternation Time Interval</i> sets the time interval.

Table 44: Parameter 27-54 Alternation at Time of Day

Option		Function
		<i>Alternate at Time of Day</i> allows selecting a specific time of day for alternating pumps. The time is set in <i>parameter 27.55 Alternation Predefined Time</i> . Alternation at Time of Day requires the real-time clock to be set.
[0]	Disabled	
[1]	Enabled	

Table 45: Parameter 27-55 Alternation Predefined Time

Range		Function
Size related*	[0-0]	<i>Alternation Predefined Time</i> is the time of day for pump alternation. This parameter is only available if <i>parameter 27-54 Alternation At Time of Day</i> is enabled.

Table 46: Parameter 27-56 Alternate Capacity is <

Range		Function
0%*	[0-100%]	<i>Alternate Capacity is <</i> requires the lead pump to be operating below this capacity before time-based alternation is allowed to take place. This feature ensures that alternation only takes place when the pump is running below a speed where interruption in operation will not affect the process. This minimizes the system disturbance caused by alternations. The value is entered as a % of the capacity of pump 1. To disable operation with <i>Alternate Capacity is <</i> , set this parameter to 0%.

Table 47: Parameter 27-58 Run Next Pump Delay

Range		Function
0.1 s*	[0.1-5 s]	<i>Run Next Pump Delay</i> is a delay between stopping the current lead pump and starting the next lead pump when alternating lead pumps. This provides time for the contactors to switch while both pumps are stopped.

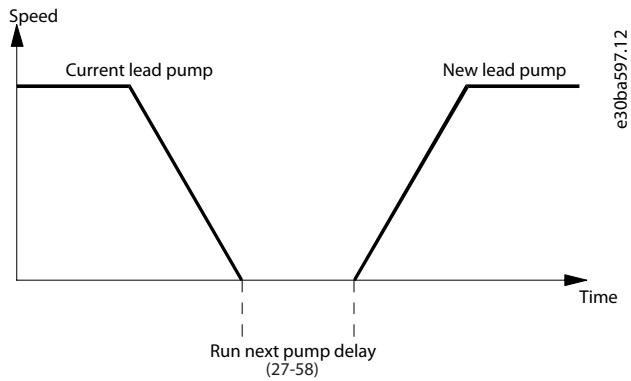


Illustration 36: Run Next Pump Delay

6.1.7 Parameter Group 27-6*, Digital Inputs

Table 48: Parameter 27-60 Terminal X66/1 Digital Input

Option		Function
[0]	No operation	
[1]	Reset	
[2]	Coast inverse	
[3]	Coast and reset inv	
[5]	DC-brake inverse	
[6]	Stop inverse	
[7]	External interlock	
[8]	Start	
[9]	Latched start	
[10]	Reversing	
[11]	Start reversing	
[14]	Jog	
[15]	Preset reference on	
[16]	Preset ref bit 0	
[17]	Preset ref bit 1	
[18]	Preset ref bit 2	
[19]	Freeze reference	
[20]	Freeze output	
[21]	Speed up	

Option	Function
[22]	Speed down
[23]	Set-up select bit 0
[24]	Set-up select bit 1
[34]	Ramp bit 0
[36]	Mains failure inverse
[51]	Hand/Auto start
[52]	Run permissive
[53]	Hand start
[54]	Auto start
[55]	DigiPot increase
[56]	DigiPot decrease
[57]	DigiPot clear
[62]	Reset counter A
[65]	Reset counter B
[66]	Sleep mode
[78]	Reset preventive maintenance word
[80]	PTC card 1
[85]	Latched pump derag
[120]	Lead pump start
[121]	Lead pump alternation
[130]	Pump 1 interlock
[131]	Pump 2 interlock
[132]	Pump 3 interlock
[133]	Pump 4 interlock
[134]	Pump 5 interlock
[135]	Pump 6 interlock
[136]	Pump 7 interlock
[137]	Pump 8 interlock
[138]	Pump 9 interlock

Table 49: Parameter 27-61 Terminal X66/3 Digital Input

Option	Function
	The options of this parameter are the same as for <i>parameter 27-60 Terminal X66/1 Digital Input</i> .

Table 50: Parameter 27-62 Terminal X66/5 Digital Input

Option	Function
	The options of this parameter are the same as for <i>parameter 27-60 Terminal X66/1 Digital Input</i> .

Table 51: Parameter 27-63 Terminal X66/7 Digital Input

Option	Function
	The options of this parameter are the same as for <i>parameter 27-60 Terminal X66/1 Digital Input</i> .

Table 52: Parameter 27-64 Terminal X66/9 Digital Input

Option	Function
	The options of this parameter are the same as for <i>parameter 27-60 Terminal X66/1 Digital Input</i> .

Table 53: Parameter 27-65 Terminal X66/11 Digital Input

Option	Function
	The options of this parameter are the same as for <i>parameter 27-60 Terminal X66/1 Digital Input</i> .

Table 54: Parameter 27-66 Terminal X66/13 Digital Input

Option	Function
	The options of this parameter are the same as for <i>parameter 27-60 Terminal X66/1 Digital Input</i> .

6.1.8 Parameter Group 27-7*, Connections

Table 55: Parameter 27-70 Relay

Option	Function	
	This parameter is an array parameter used to set up the function of the option relays. Depending on which option is installed, only the available relays are visible. If VLT® Extended Cascade Controller MCO 101 is installed, relays 10–12 are visible. If VLT® Advanced Cascade Controller MCO 102 is installed, relays 13–20 are visible. In both cases, the standard relays (relay 1 and relay 2) are accessible as well as the relays in the B option VLT® Relay Card MCB 105 (if that option is installed in combination with advanced cascade). To set up the function of each relay, select the specific relays and then select the function. If the function option [0] <i>Standard Relay</i> is selected, the relay can be used as general purpose relay and the wanted function can then be set up in <i>parameter group 5-4* Relays</i> .	
[0]	Standard Relay	Enable follower drive X
[1]	Drive 2 Enable	
[2]	Drive 3 Enable	
[3]	Drive 3 Enable	
[4]	Drive 3 Enable	
[5]	Drive 3 Enable	
[6]	Drive 3 Enable	
[7]	Drive 3 Enable	
[8]	Pump 1 to Drive 1	
[9]	Pump 1 to Drive 2	

Option		Function
[10]	Pump 1 to Drive 3	
[11]	Pump 1 to Drive 4	
[12]	Pump 1 to Drive 5	
[13]	Pump 1 to Drive 6	
[14]	Pump 1 to Drive 7	
[15]	Pump 1 to Drive 8	
[16]	Pump 2 to Drive 1	
[17]	Pump 2 to Drive 2	
[18]	Pump 2 to Drive 3	
[19]	Pump 2 to Drive 4	
[20]	Pump 2 to Drive 5	
[21]	Pump 2 to Drive 6	
[22]	Pump 2 to Drive 7	
[23]	Pump 2 to Drive 8	
[24]	Pump 3 to Drive 1	
[25]	Pump 3 to Drive 2	
[26]	Pump 3 to Drive 3	
[27]	Pump 3 to Drive 4	
[28]	Pump 3 to Drive 5	
[29]	Pump 3 to Drive 6	
[30]	Pump 3 to Drive 7	
[31]	Pump 3 to Drive 8	
[32]	Pump 4 to Drive 1	
[33]	Pump 4 to Drive 2	
[34]	Pump 4 to Drive 3	
[35]	Pump 4 to Drive 4	
[36]	Pump 4 to Drive 5	
[37]	Pump 4 to Drive 6	
[38]	Pump 4 to Drive 7	
[39]	Pump 4 to Drive 8	
[40]	Pump 5 to Drive 1	
[41]	Pump 5 to Drive 2	

Option		Function
[42]	Pump 5 to Drive 3	
[43]	Pump 5 to Drive 4	
[44]	Pump 5 to Drive 5	
[45]	Pump 5 to Drive 6	
[46]	Pump 5 to Drive 7	
[47]	Pump 5 to Drive 8	
[48]	Pump 6 to Drive 1	
[49]	Pump 6 to Drive 2	
[50]	Pump 6 to Drive 3	
[51]	Pump 6 to Drive 4	
[52]	Pump 6 to Drive 5	
[53]	Pump 6 to Drive 6	
[54]	Pump 6 to Drive 7	
[55]	Pump 6 to Drive 8	
[56]	Pump 7 to Drive 1	
[57]	Pump 7 to Drive 2	
[58]	Pump 7 to Drive 3	
[59]	Pump 7 to Drive 4	
[60]	Pump 7 to Drive 5	
[61]	Pump 7 to Drive 6	
[62]	Pump 7 to Drive 7	
[63]	Pump 7 to Drive 8	
[64]	Pump 8 to Drive 1	
[65]	Pump 8 to Drive 2	
[66]	Pump 8 to Drive 3	
[67]	Pump 8 to Drive 4	
[68]	Pump 8 to Drive 5	
[69]	Pump 8 to Drive 6	
[70]	Pump 8 to Drive 7	
[71]	Pump 8 to Drive 8	
[72]	Pump 1 to Mains	
[73]	Pump 2 to Mains	

Option		Function
[74]	Pump 3 to Mains	
[75]	Pump 4 to Mains	
[76]	Pump 5 to Mains	
[77]	Pump 6 to Mains	
[78]	Pump 7 to Mains	
[79]	Pump 8 to Mains	

6.1.9 Parameter Group 27-9*, Readouts

Table 56: Parameter 27-91 Cascade Reference

Range	Function
0%* [-200 - 200%]	<i>Cascade Reference</i> is a readout parameter that shows the reference output for use with the follower drives. This reference is available even when the master drive is stopped. This is the speed that the drive operates at or would be operating at if it was on. It is scaled as a percentage of <i>parameter 4-13 Motor Speed High Limit [RPM]</i> or <i>parameter 4-14 Motor Speed High Limit [Hz]</i> .

Table 57: Parameter 27-92 % Of Total Capacity

Range	Function
0%* [0-0%]	<i>% of Total Capacity</i> is a readout parameter that shows the system operating point as a % capacity of total system capacity. 100% means that all pumps are on at full speed.

Table 58: Parameter 27-93 Cascade Option Status

Option	Function
[0]	Disabled The cascade option is not used.
[1]	Off
[2]	Running
[3]	Running at FSBW
[4]	Jogging
[5]	In open loop
[6]	Freezed
[7]	Coast
[8]	Alarm
[9]	Staging
[10]	Destaging
[11]	Alternating
[12]	All offline
[13]	Cascade CTL sleep

Table 59: Parameter 27-94 Cascade System Status

Range	Function
0* [0-25]	<i>Cascade System Status</i> is a readout parameter that shows the status of each individual pump.

Table 60: Parameter 27-95 Advanced Cascade Relay Output [bin]

Range	Function
0* [0-255]	<i>Advanced Cascade Relay Output [bin]</i> is a readout parameter that shows the status of each individual relay. From left to right, the bits correspond to the relays 13, 14, 15, 16, 17, 18, 19, 20, respectively.

6.2 Parameter Lists

N O T I C E

*Parameter group 25-** Cascade Controller* is only to be used for the Basic Cascade Controller or if 1 of the options is used for extending the number of pumps of the Basic Cascade Controller. In all other cases, use *parameter group 27-** Cascade CTL Option*.

6.2.1 25-** Cascade Controller

Table 61: Parameter List, 25-** Cascade Controller

Parameter number	Parameter description	Default value	4 setup	Change during operation	Conversion index	Type
25-0* System Settings						
25-00	Cascade Controller	ExpressionLimit	2 setups	FALSE	–	Uint8
25-02	Motor Start	[0] Direct on line	2 setups	FALSE	–	Uint8
25-04	Pump Cycling	ExpressionLimit	All setups	TRUE	–	Uint8
25-05	Fixed Lead Pump	ExpressionLimit	2 setups	FALSE	–	Uint8
25-06	Number of Pumps	2 N/A	2 setups	FALSE	0	Uint8
25-2* Bandwidth Settings						
25-20	Staging Bandwidth	ExpressionLimit	All setups	TRUE	0	Uint8
25-21	Override Bandwidth	100%	All setups	TRUE	0	Uint8
25-22	Fixed Speed Bandwidth	casco-staging-bandwidth (P2520)	All setups	TRUE	0	Uint8
25-23	SBW Staging Delay	15 s	All setups	TRUE	0	Uint16
25-24	SBW Destaging Delay	15 s	All setups	TRUE	0	Uint16
25-25	OBW Time	10 s	All setups	TRUE	0	Uint16
25-26	Destage at No-flow	[0] Disabled	All setups	TRUE	–	Uint8
25-27	Stage Function	ExpressionLimit	All setups	TRUE	–	Uint8
25-28	Stage Function Time	15 s	All setups	TRUE	0	Uint16
25-29	Destage Function	ExpressionLimit	All setups	TRUE	–	Uint8
25-30	Destage Function Time	15 s	All setups	TRUE	0	Uint16
25-4* Staging Settings						

Parameter number	Parameter description	Default value	4 setup	Change during operation	Conversion index	Type
25-40	Ramp Down Delay	10 s	All setups	TRUE	-1	Uint16
25-41	Ramp Up Delay	2 s	All setups	TRUE	-1	Uint16
25-42	Staging Threshold	ExpressionLimit	All setups	TRUE	0	Uint8
25-43	Destaging Threshold	ExpressionLimit	All setups	TRUE	0	Uint8
25-44	Staging Speed [RPM]	0 RPM	All setups	TRUE	67	Uint16
25-45	Staging Speed [Hz]	0 Hz	All setups	TRUE	-1	Uint16
25-46	Destaging Speed	0 RPM	All setups	TRUE	67	Uint16
25-47	Destaging Speed	0 Hz	All setups	TRUE	-1	Uint16
25-5* Alternation Settings						
25-50	Lead Pump Alternation	ExpressionLimit	All setups	TRUE	-	Uint8
25-51	Alternation Event	[0] External	All setups	TRUE	-	Uint8
25-52	Alternation Time Interval	24 h	All setups	TRUE	74	Uint16
25-53	Alternation Timer Value	0 N/A	All setups	TRUE	0	VisStr[7]
25-54	Alternation Predefined Time	ExpressionLimit	All setups	TRUE	0	TimeOfDayWo-Date
25-55	Alternate if Load < 50%	[1] Enabled	All setups	TRUE	-	Uint8
25-56	Staging Mode at Alternation	[0] Slow	All setups	TRUE	-	Uint8
25-58	Run Next Pump Delay	0.1 s	All setups	TRUE	-1	Uint16
25-59	Run on Mains Delay	0.5 s	All setups	TRUE	-1	Uint16
25-8* Status						
25-80	Cascade Status	0 N/A	All setups	TRUE	0	VisStr[25]
25-81	Pump Status	0 N/A	All setups	TRUE	0	VisStr[25]
25-82	Lead Pump	0 N/A	All setups	TRUE	0	Uint8
25-83	Relay Status	0 N/A	All setups	TRUE	0	VisStr[4]
25-84	Pump ON Time	0 h	All setups	TRUE	74	Uint32
25-85	Relay ON Time	0 h	All setups	TRUE	74	Uint32
25-86	Reset Relay Counters	[0] Do not reset	All setups	TRUE	-	Uint8
25-9* Service						
25-90	Pump Interlock	[0] Off	All setups	TRUE	-	Uint8
25-91	Manual Alternation	0 N/A	All setups	TRUE	0	Uint8

6.2.2 27-** Cascade CTL Option

Table 62: Parameter List, 27-** Cascade CTL Option

Parameter number	Parameter description	Default value	4 setup	Change during operation	Conversion index	Type
27-0* Control & Status						
27-01	Pump Status	[0] Ready	All setups	TRUE	–	Uint8
27-02	Manual Pump Control	[0] No Operation	2 setups	TRUE	–	Uint8
27-03	Current Runtime Hours	0 h	All setups	TRUE	74	Uint32
27-04	Pump Total Lifetime Hours	0 h	All setups	TRUE	74	Uint32
27-1* Configuration						
27-10	Cascade Controller	null	2 setups	FALSE	–	Uint8
27-11	Number of Drives	ExpressionLimit	2 setups	FALSE	0	Uint8
27-12	Number of Pumps	ExpressionLimit	2 setups	FALSE	0	Uint8
27-14	Pump Capacity	100%	2 setups	FALSE	0	Uint16
27-16	Runtime Balancing	[0] Balanced Priority 1	2 setups	TRUE	–	Uint8
27-17	Motor Starters	[0] Direct Online	2 setups	FALSE	–	Uint8
27-18	Spin Time for Unused Pumps	ExpressionLimit	All setups	TRUE	0	Uint16
27-19	Reset Current Runtime Hours	[0] Do not reset	All setups	TRUE	–	Uint8
27-2* Bandwidth Settings						
27-20	Normal Operating Range	ExpressionLimit	All setups	TRUE	0	Uint8
27-21	Override Limit	100%	All setups	TRUE	0	Uint8
27-22	Fixed Speed Only Operating Range	ExpressionLimit	All setups	TRUE	0	Uint8
27-23	Staging Delay	15 s	All setups	TRUE	0	Uint16
27-24	Destaging Delay	15 s	All setups	TRUE	0	Uint16
27-25	Override Hold Time	10 s	All setups	TRUE	0	Uint16
27-27	Min Speed Destage Delay	ExpressionLimit	All setups	TRUE	0	Uint16
27-3* Staging Speed						
27-30	Auto Tune Staging Speeds	[1] Enabled	All setups	TRUE	–	Uint8
27-31	Stage On Speed [RPM]	ExpressionLimit	All setups	TRUE	67	Uint16
27-32	Stage On Speed [Hz]	ExpressionLimit	All setups	TRUE	-1	Uint16
27-33	Stage Off Speed [RPM]	ExpressionLimit	All setups	TRUE	67	Uint16
27-34	Stage Off Speed [Hz]	ExpressionLimit	All setups	TRUE	-1	Uint16
27-4* Staging Settings						

Parameter number	Parameter description	Default value	4 setup	Change during operation	Conversion index	Type
27-40	Auto Tune Staging Settings	[0] Disabled	All setups	TRUE	–	Uint8
27-41	Ramp Down Delay	10.0 s	All setups	TRUE	-1	Uint6
27-42	Ramp Up Delay	2.0 s	All setups	TRUE	-1	Uint16
27-43	Staging Threshold	ExpressionLimit	All setups	TRUE	0	Uint8
27-44	Destaging Threshold	ExpressionLimit	All setups	TRUE	0	Uint8
27-45	Staging Speed [RPM]	0 RPM	All setups	TRUE	67	Uint16
27-46	Staging Speed [Hz]	0.0 Hz	All setups	TRUE	-1	Uint16
27-47	Destaging Speed [RPM]	0 RPM	All setups	TRUE	67	Uint16
27-48	Destaging Speed [Hz]	0.0 Hz	All setups	TRUE	-1	Uint16
27-5* Alternate Settings						
27-50	Automatic Alternation	[0] Disabled	All setups	FALSE	–	Uint8
27-51	Alternation Event	Null	All setups	TRUE	–	int8
27-52	Alternation Time Interval	0 min	All setups	TRUE	70	Uint16
27-53	Alternation Timer Value	0 min	All setups	TRUE	70	Uint16
27-54	Alternation At Time of Day	[0] Disabled	All setups	TRUE	–	Uint8
27-55	Alternation Predefined Time	ExpressionLimit	All setups	TRUE	0	TimeOfDayWo-Date
27-56	Alternate Capacity is <	0%	All setups	TRUE	0	Uint8
27-58	Run Next Pump Delay	0.1 s	All setups	TRUE	-1	Uint16
27-6* Digital Inputs						
27-60	Terminal X66/1 Digital Input	[0] No operation	All setups	TRUE	–	Uint8
27-61	Terminal X66/3 Digital Input	[0] No operation	All setups	TRUE	–	Uint8
27-62	Terminal X66/5 Digital Input	[0] No operation	All setups	TRUE	–	Uint8
27-63	Terminal X66/7 Digital Input	[0] No operation	All setups	TRUE	–	Uint8
27-64	Terminal X66/9 Digital Input	[0] No operation	All setups	TRUE	–	Uint8
27-65	Terminal X66/11 Digital Input	[0] No operation	All setups	TRUE	–	Uint8
27-66	Terminal X66/13 Digital Input	[0] No operation	All setups	TRUE	–	Uint8
27-7* Connections						
27-70	Relay	[0] Standard Relay	2 setups	FALSE	–	Uint8
27-9* Readouts						
27-91	Cascade Reference	0.0%	All setups	TRUE	-1	Int16
27-92	% Of Total Capacity	0%	All setups	TRUE	0	Uint16

Parameter number	Parameter description	Default value	4 setup	Change during operation	Conversion index	Type
27-93	Cascade Option Status	[0] Disabled	All setups	TRUE	–	Uint8
27-94	Cascade System Status	0 N/A	All setups	TRUE	0	VisStr[25]
27-95	Advanced Cascade Relay Output [bin]	0 N/A	All setups	TRUE	0	Uint16

7 Configuration Example

7.1 Master/Follower

In this example of a master/follower configuration with 3 variable-speed pumps, it is assumed that the pressure transmitter is used as feedback sensor and has a range from 0–10 bar. Furthermore, an internal reference is used.

For more detailed information on the master/follower application and on the staging/destaging principle, see [3.2.2 Hardware Configuration for Master/Follower Cascade Control](#) and [5.1 Configuration of the Extended and Advanced Cascade Controllers](#).

The required steps for the configuration are:

- Basic settings for the master and for the follower (motor data, display, and so on).
- Configuration of the master.
- Configuration of 1 of the followers.
- Copying the setting with the LCP from this follower to the other follower.

7.1.1 Basic Settings

The basic settings of master/follower configurations consist of:

- Basic motor settings for master and follower drives, see [7.1.1.1 Basic Settings, Master and Follower](#).
- Display settings for master and follower drives, see [7.1.1.2 Display Settings, Master and Follower](#).

7.1.1.1 Basic Settings, Master and Follower

Table 63: Basic Settings

Basic settings (master and follower)	Example/remarks
Parameter 0-02 Motor Speed Unit	[1] Hz
Parameter 1-20 Motor Power [kW]	–
Parameter 1-22 Motor Voltage [V]	–
Parameter 1-23 Motor Frequency [Hz]	50
Parameter 1-24 Motor Current [A]	–
Parameter 1-25 Motor Nominal Speed [RPM]	–
Parameter 1-29 Automatic Motor Adaptation (AMA)	–
Parameter 3-41 Ramp 1 Ramp Up Time [s]	The settings must be the same for master and follower.
Parameter 3-42 Ramp 1 Ramp Down Time [s]	
Parameter 4-11 Motor Speed Low Limit [RPM]	
Parameter 4-12 Motor Speed Low Limit [Hz]	
Parameter 4-13 Motor Speed High Limit [RPM]	
Parameter 4-14 Motor Speed High Limit [Hz]	

N O T I C E

Ensure that the motor is running properly before setting the master drive to closed-loop operation.

7.1.1.2 Display Settings, Master and Follower

Table 64: Display Settings

Display settings - master drive	Example
Parameter 0-20 Display Line 1.1 Small	[1601] Reference

Display settings - master drive	Example
Parameter 0-21 Display Line 1.2 Small	[1652] Feedback
Parameter 0-22 Display Line 1.3 Small	[1614] Motor Current
Parameter 0-23 Display Line 2 Large	[1613] Frequency
Parameter 0-24 Display Line 3 Large	[2794] Cascade System Status
Display settings - follower drives	
Parameter 0-20 Display Line 1.1. Small	[1650] External Reference
Parameter 0-24 Display Line 3 Large	[1613] Frequency

7.1.2 Master Drive Settings

The master drive settings for master/follower configurations consist of:

- Configuration settings, see [7.1.2.1 Configuration Settings](#)
- Bandwidth settings, see [7.1.2.2 Bandwidth Settings](#)
- Staging speed settings, see [7.1.2.3 Staging Speed Settings](#)
- Alternate settings, see [7.1.2.4 Alternate Settings](#)
- Connection settings, see [7.1.2.5 Connection Settings](#)

7.1.2.1 Configuration Settings

Table 65: Master Drive Settings, Configuration

27-1* Configuration	Example
Parameter 27-10 Cascade Controller	[1] Master/Follower
Parameter 27-11 Number of Drives	3
Parameter 27-16 Runtime Balancing	[0] Array, Balanced Priority 1
Parameter 27-18 Spin Time for Unused Pumps	0 [s], Off
Parameter 27-19 Reset Current Runtime Hours	[1] Do reset

7.1.2.2 Bandwidth Settings

Table 66: Master Drive Settings, Bandwidth Settings

27-2* Bandwidth settings	Example
Parameter 27-21 Override Limit	100 [%]
Parameter 27-23 Staging Delay	15 (s)
Parameter 27-23 Destaging Delay	15 (s)

7.1.2.3 Staging Speed Settings

Table 67: Master Drive Settings, Staging Speeds

27-3* Staging Speeds	Example/Remarks
Parameter 27-30 Auto Tune Staging Speeds	[1] Enabled
Parameter 27-31 Stage On Speed [RPM]	Arrays for the staging speeds.
Parameter 27-32 Stage On Speed [Hz]	

27-3* Staging Speeds	Example/Remarks
Parameter 27-33 Stage Off Speed [RPM]	
Parameter 27-34 Stage Off Speed [Hz]	

7.1.2.4 Alternate Settings

Table 68: Master Drive Settings, Alternate Settings

27-5* Alternate Settings	Example
Parameter 27-52 Alternation Time Interval	0 (min), Disabled
Parameter 27-54 Alternation At Time of Day	[0] Disabled
Parameter 27-56 Alternate Capacity is <	0 (s), Off

7.1.2.5 Connection Settings

N O T I C E

An array parameter is used for configuring the output of the master drive for the start signal of the follower drives.

Table 69: Master Drive Settings, Connections

27-7* Connections	Example
Parameter 27-70.0 Relay 1	[1] Drive 2 Enable
Parameter 27-70.1 Relay 2	[2] Drive 3 Enable

7.1.3 Follower Drive Settings

Follower drive must be configured for open-loop operation with basic settings as described in [7.1.1 Basic Settings](#). Configure only 1 of the followers and copy the settings via the LCP.

Terminal 29 is used as a pulse input for the reference signal and must be scaled.

The settings of the follower drives consist of:

- Open-loop settings, see [7.1.3.1 Open-loop Settings](#)
- Digital in/out settings, see [7.1.3.2 Digital In/Out Settings](#)

7.1.3.1 Open-loop Settings

Table 70: Open-loop Settings, Follower Drive

Open-loop settings	Example/remarks
Parameter 1-00 Configurations Mode	[0] Open loop
Parameter 3-02 Minimum Reference	0
Parameter 3-03 Maximum Reference	50 [Hz]
Parameter 3-15 Reference 1 Source	[7] Pulse Input 29

7.1.3.2 Digital In/Out Settings

Table 71: Follower Drive Settings, Digital In/Out

5-** Digital in/out (follower)	Example/remarks
Parameter 5-02 Terminal 29 Mode	[0] Input

5-** Digital in/out (follower)	Example/remarks
Parameter 5-13 Terminal 29 Digital Input	[32] Pulse Input
Parameter 5-50 Terminal 29 Low Frequency	0 [Hz]
Parameter 5-51 Terminal 29 High Frequency	6000 [Hz]
Parameter 5-52 Terminal 29 Low Ref. Value	0
Parameter 5-53 Terminal 29 High Ref. Value	50 [Hz]
Parameter 5-10 Terminal 18 Digital Input	[8] Start

7.1.4 Configuring Sleep Mode

This procedure describes how to configure the drive for destaging the last variable-speed pump in applications with more than 1 drive.

Procedure

1. Set *parameter 27-34.01* higher than the minimum speed in *parameter 4-11 Motor Speed Low Limit [RPM]/parameter 4-12 Motor Speed Low Limit [Hz]* to enable the sleep function (setting it to 0 disables the function).
2. Set *parameter 27-21 Override Limit* to wake up the application.

➔ After wake-up, the pump with the least running hours starts.

NOTICE

If the master drive does not wake up properly, the drive is not able to reach its destaging speed and the delays in *parameter group 27-** Cascade CTL Option* have to be adjusted.

Example

This is an example of an application with 3 pumps with sleep mode enabled.

Table 72: Example Settings for Parameter Group 27-3* Staging Speeds

Stage	Stage ON [Hz]	Stage OFF [Hz]
1	48.5 (<i>parameter 2732.1</i>)	30 (<i>parameter 2734.1</i>)
2	48.5 (<i>parameter 2732.2</i>)	40 (<i>parameter 2734.2</i>)
3	– (<i>parameter 2732.3</i>)	42 (<i>parameter 2734.3</i>)

- *Stage* refers to the stage the cascade is running in (stage 1 ⇒ cascade is running in stage 1, only 1 pump is running).
- Pumps 1 and 3 are started on 48.5 Hz.
- Pump 3 is stopped on 42 Hz, pump 2 is stopped on 40 Hz, and pump 1 is stopped on 30 Hz.
- It might be necessary to fine-adjust the stage on/off speeds to optimize the energy consumption if not autotuned. It is recommended to enable Auto Tune Staging Speeds in *parameter 27-30 Auto Tune Staging Speeds*.

NOTICE

Parameter 2732.3 is irrelevant in this case because there is nothing left to stage on in stage 3.

NOTICE

Alternatively, the sleep mode can also be configured by using *parameter 22-22 Low Speed Detection* and *parameter group 22-4* Sleep Mode*.

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