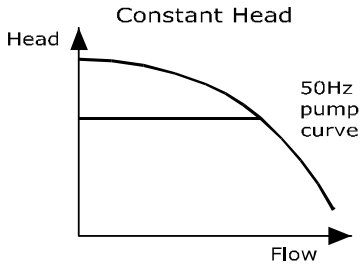
■ Contents

■ Functionality

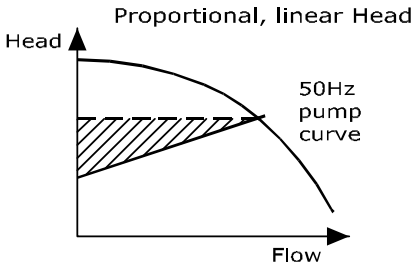
Sensorless Pump Control (Sensorless) has been developed to enable the drive to control the pressure (Head) in a circuit with non-compressible liquid, e.g. water, WITHOUT using a pressure transducer. This has several advantages such as:

- Cost savings as there is no need for a pressure transducer.
- Increased reliability, as there are no additional components (transducer, cable, connections) that can cause malfunction.
- No maintenance and exchange of pressure transmitters.
- Very dynamic with a response time of only 1-2 seconds.
- Increased energy savings.

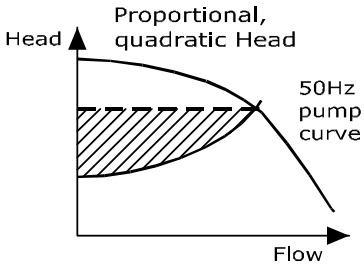
Sensorless contains three different ways of controlling the pressure where the choice depends on the type of application.



175ZA911.10



175ZA912.10



175ZA913.10

Constant Head: The controller keeps a constant head across the pump regardless of the flow through the pump. Does not take pipe friction loss into account.

Proportional linear head: The controller increases the head across the pump when the flow through the pump increases, and it decreases the head when the flow decreases. Takes pipe friction loss into account, with a linear approximation to the real system curve.

Proportional, quadratic Head: Same as Proportional Head, but with a quadratic Head curve instead of linear. Takes pipe friction loss into account, with a quadratic approximation to the real system curve.

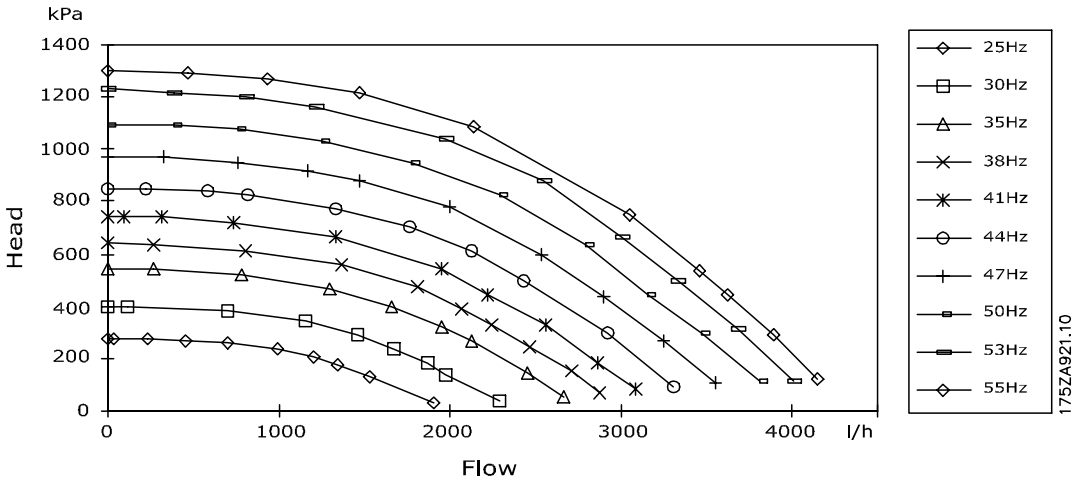
In the manual, these three types of pressure control are referred to as the *user-defined head*.

Marked area: Energy savings compared to constant head control.
(P = K x Flow x Head)

■ How Does It Work?

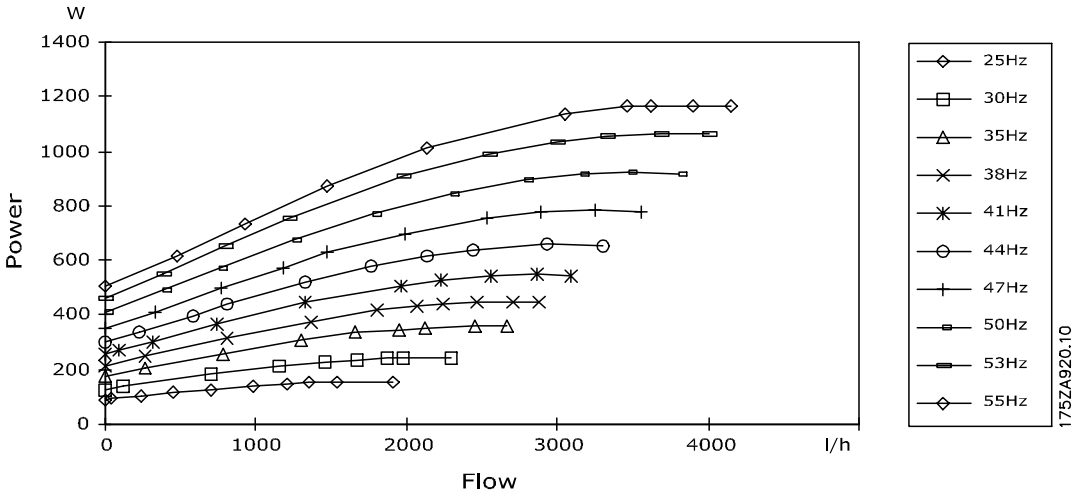
Sensorless is based on the relations between frequency, flow, head and power. So consequently the drive needs the data shown in the graphs below as input for the calculations. The data are pump specific and need to be found by measurement. Alternatively, the data can be found by data sheet from the pump supplier if accurate enough.
The graph below shows an example of some measured values for flow/head on a typical centrifugal pump.

Head/flow (H/Q) Curves on a 1.5 kW pump



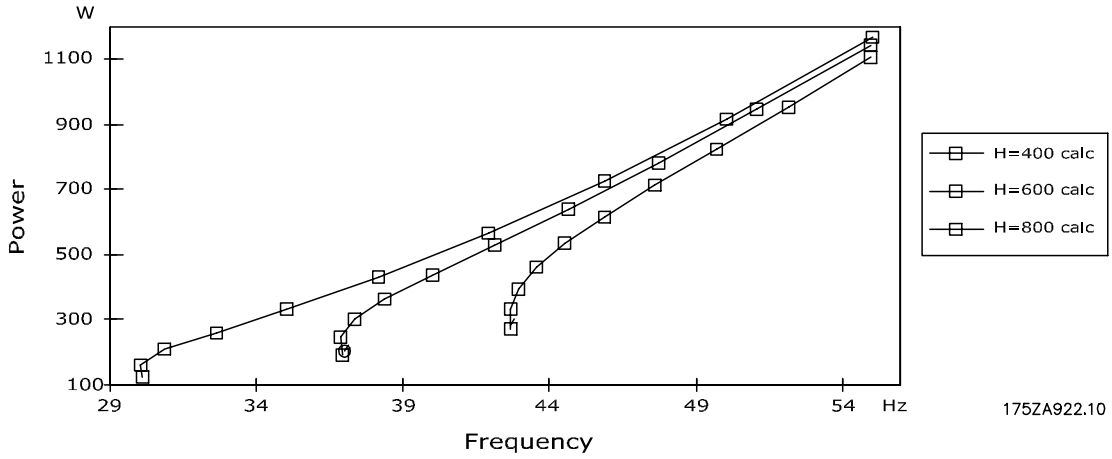
The graph below shows the measured values for flow/power.

Power/flow (P/Q) Curves on a 1.5 kW pump



With these values it is possible to create the relation between Power and frequency (P/f curve).

Power/frequency (P/f) Curves on a 1.5 kW pump

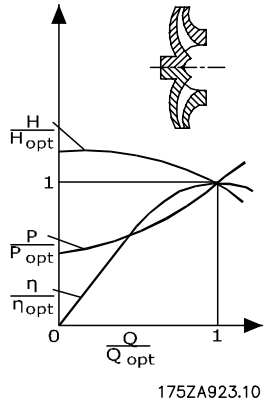


With these relations it is now possible to control the pressure (e.g. keeping it constant if that is desired) by controlling the frequency according to the power measurement.

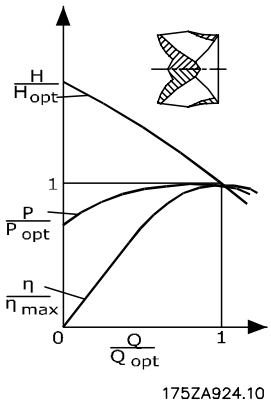
■ Limitations

A criteria for Sensorless to work is that there must be a clear one-to-one relation between head and flow, and power and flow, (i.e. only one H-value to one Q-value and opposite) as this forms the basis for the P/f-curve.

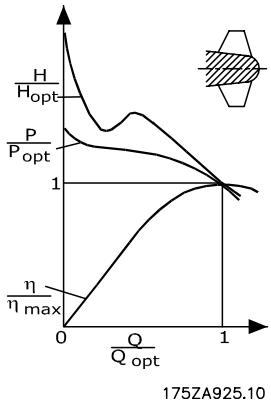
Sensorless can be used with centrifugal pumps that have radial impeller. On pumps with mixed flow impellers there is only limited use as the power curve is typically flat at high flow rates. A centrifugal pump with axial impeller cannot be controlled with sensorless control due to the particular shape of the head curve. The graphics below show typical characteristics for the different pump types.



Radial impeller
n_q=20 min^{-1}
Possible



Mixed flow impeller
n_q=80 min^{-1}
Limited



Axial impeller
n_q=200 min^{-1}
Not possible

Other limitations: Sensorless control is limited to non-compressible liquids such as water. Furthermore the solution is recommended only in closed systems.

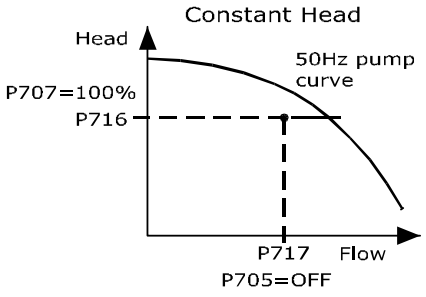
This parameter activates the Sensorless control:

Par. No.	Par. Name	Selection	Default	Description
Par. 700	(SENSOR-LESS CON-TROL)	FCM: OFF/ON VLT 6000: ENABLE/DISABLE	OFF/DISABLE	Set parameter to enable/ON to activate Sensorless control. Please observe that this parameter must be set to disable when doing measurements.

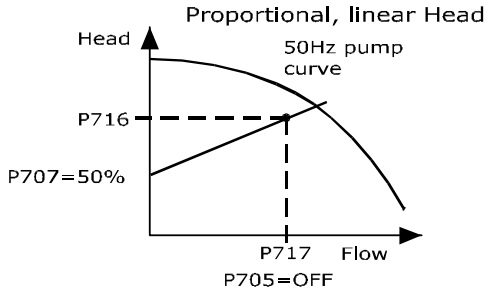
The following parameters must be set to make Sensorless work:

VLT 6000	FCM
Par. 100 must be OPEN LOOP	Par. 003 must be LOCAL
Par. 101 must be MULTIPLE MOTORS	Par. 100 must be OPEN LOOP
-	Par. 101 must be VT HIGH

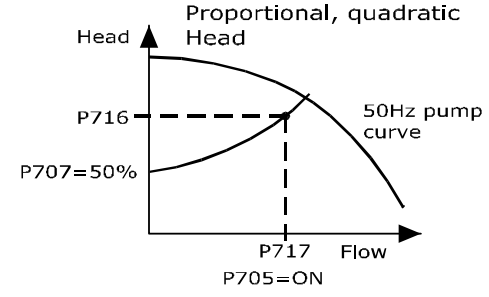
The following parameters determine the user-defined head for the system.



175ZA914.10



175ZA915.10



175ZA916.10

■ Par. 705 Quadratic Head

Par. 705 Quadratic head (QUADRATIC HEAD)

Value:

ON/OFF ★ OFF

Function:

Used when selecting the desired type of Sensorless control: Quadratic head or linear (proportional or constant) head.

Description of choice:

OFF: Generates a linear head/flow reference between Head Q_{min} (Par. 707) and Head working point (Par. 716).
ON: Generates a quadratic head/flow reference between Head Q_{min} (Par. 707) and Head working point (Par. 716)

■ Par. 707 Head Qmin

Par. 707 Head Q_{min} (HEAD QMIN)

Value:

0-100% ★ 100%

Function:

Sets the head reference at zero flow as a percentage of the value specified in Par. 716.

Description of choice:

Set a value between 0 and 100%.

■ Par. 716 Head Working Point

Par. 716 Head Working Point
(HEAD WORK. POINT)

Value:

FCM
0-2000 kPa ✯ 10 kPa
VLT 6000
0-20000 kPa ✯ 10 kPa

Function:

Defines the head at the working point.

Description of choice:

Set the value in kPa according to the desired head working point parameter 717. Note the difference in range for FCM and VLT 6000.

■ Par. 717 Flow Working Point

Par. 717 Flow Working Point
(FLOW WORK. POINT)

Value:

0-999 l/s ✯ 1 l/s

Function:

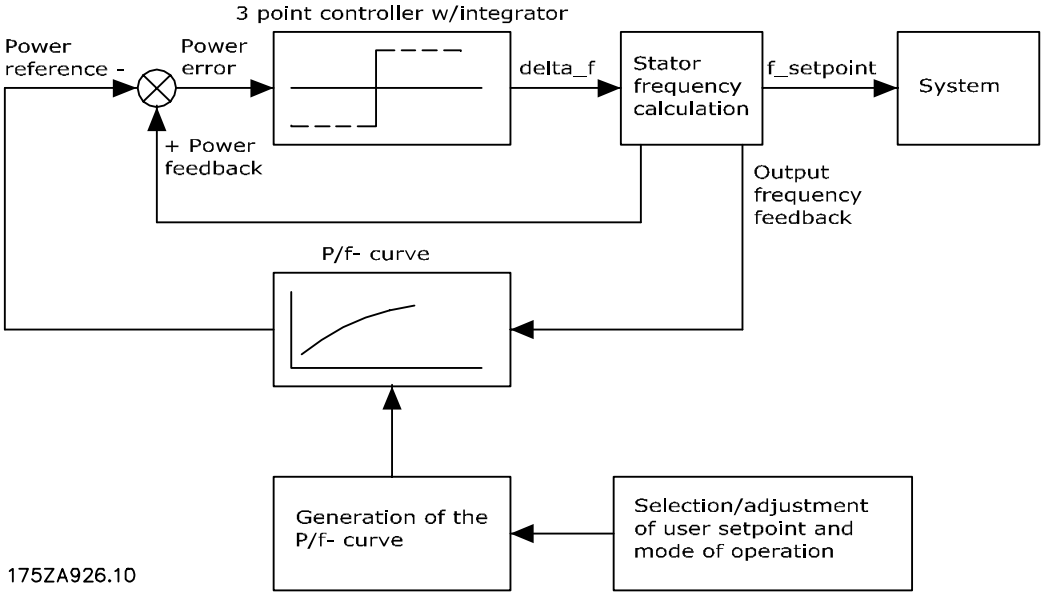
Defines the flow at the working point.

Description of choice:

Set the value in l/s according to the desired flow working point parameter 716.

■ Control Principle

The control principle builds on converting an internal feedback of inverter parameters into a power reference that the controller uses to adjust the output frequency. The control scheme is illustrated below.



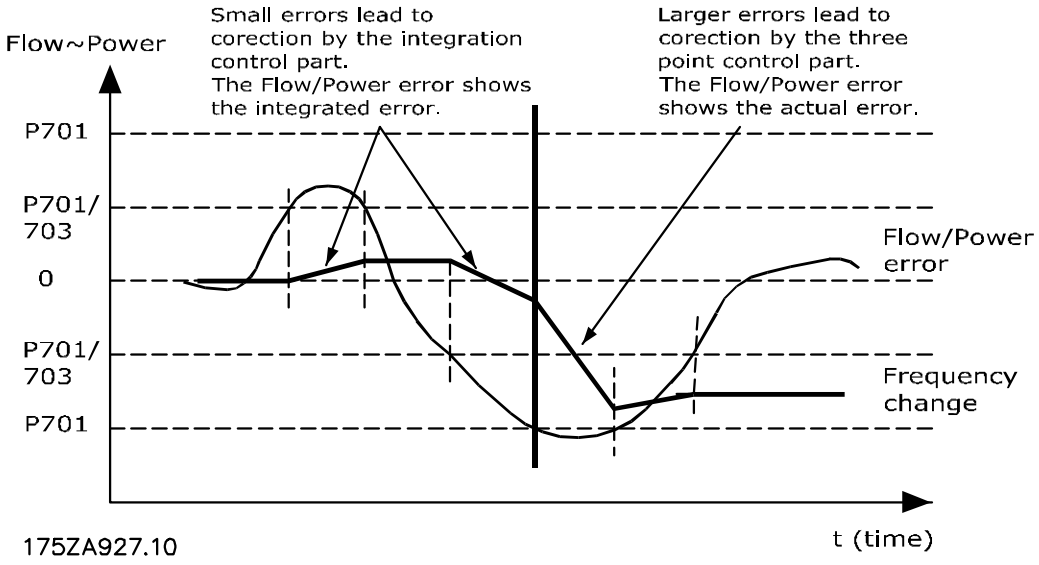
The control part is divided into two parts:

- The *Integration control part* sums up the actual power error and whenever the threshold defined as the value $\frac{\text{Power error (par. 701)}}{\text{Integral Power (par. 703)}}$ is exceeded, the actual speed is increased resp.

decreased with the value x $\frac{\text{Delta freq. (par. 702)}}{\text{Integral freq. (par. 704)}}$

- The *Three point control part* uses par. 701 to define the threshold. If the deviation to the actual power setpoint exceeds the value in par. 701, the speed increases respectively decreases with the value in par. 702.

For VLT 6000 the updating takes place every 160ms and for FCM every 20ms.


Flow~Power
Small errors lead to corection by the integration control part.
The Flow/Power error shows the integrated error.
Larger errors lead to corection by the three point control part.
The Flow/Power error shows the actual error.
P701
P701/ 703
0
P701/ 703
P701
Flow/Power error
Frequency change
t (time)
175ZA927.10

■ Parameter Setting - Control

The following parameters are used for setting up the control:

■ Par. 701 Power Error

Par. 701 Power Error
(POWER ERROR)

Value:

FCM: 1-50W	✯ 20W
VLT 6000: 1-250W	✯ 20W

Function:

See description under "Control Principle".

Description of choice:

A small value leads to a lower threshold for the integration part of the controller, and thereby faster reaction. Larger pumps will require a larger value.

■ Par. 702 Delta Frequency

Par. 702 Delta Frequency
(DELTA FREQUENCY)

Value:

0,1-1 Hz	✯ 0,4 Hz

Function:

See description under "Control Principle".

Description of choice:

A small value leads to a smaller frequency step in the integration control part. This means slower but more precise control.

■ Par. 703 Integral Power

Par. 703 Integral Power
(INTEGRAL POWER)

Value:

1-100	✯ 20

Function:

See description under "Control Principle".

Description of choice:

A small value leads to a higher threshold for the integration part of the controller, and thereby faster reaction.

■ Par. 704 Integral Frequency

Par. 704 Integral Frequency
(INTEGRAL FREQUENCY)

Value:

1-100	✯ 20

Function:

See description under "Control Principle".

Description of choice:

A small value leads to a larger frequency step in the three-point control part. This means faster but rougher control.

■ Power Compensation

Par. 708 Power Compensation
(POWER COMP)

Value:

VLT 6000: -1000W-1000W	✯ 0
FCM: -100W-100W	✯ 0

Function:

To obtain a more precise control and read-out, it can be an advantage to correct the total power in the P/f table by an offset, positive or negative. Example on effect: On a 1½ kW pump, about -30W can change the flow read-out from 2.2 l/s to 1.8l/s. at max flow of 10 l/s.

Description of choice:

When preparing the system for sensorless control, compare the calculated flow values with real measured values. If there is a deviation in figures, this can be caused by an offset in values. Enter the value necessary to obtain as small a deviation as possible.

■ Analog Output

Terminal 45 on the VLT 6000 and terminal 9 on the FCM can be used to read out either flow or head.

VLT 6000:
Par. 321 Terminal 45, output

FCM:
Par. 304 Terminal 9, output

Value
The following choices have been added:

Choice	Choice no. FCM	Choice no. VLT 6000
SENS. FLOW = 0-20 mA	[22]	[44]
SENS. FLOW = 4-20 mA	[23]	[45]
SENS. HEAD = 0-20 mA	[24]	[46]
SENS. HEAD = 4-20 mA	[25]	[47]

■ Par. 720 AO Max Value

Par. 720 AO Max Value
(AO MAX VALUE)

Value:

1-9999 ★ 1

Function:

This parameter is used to convert the current signal to a head or flow value.

Description of choice:

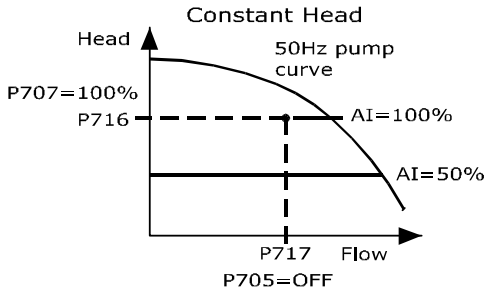
Enter the maximum value for head or flow, at which the analog output must give 20 mA.
Example:
Par. 321 is SENS. HEAD = 4-20 mA
Par. 720 is 200 (kPa)
The actual head is 100kPa. That brings terminal 45 up to 12mA.

■ Analog Input

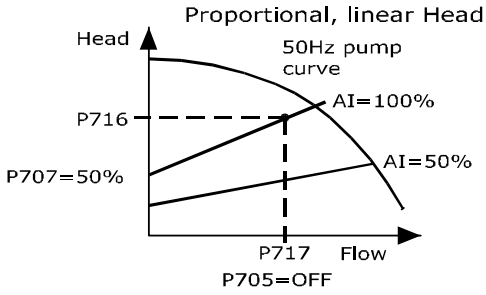
It is possible to reduce the user-defined head with the following parameters.

Drive	Input	Parameter	Choice	Value
FCM	DI 9	332	[38]	SENSORLESS
VLT 6000	AI 53	308	[10]	SENSORLESS HEAD

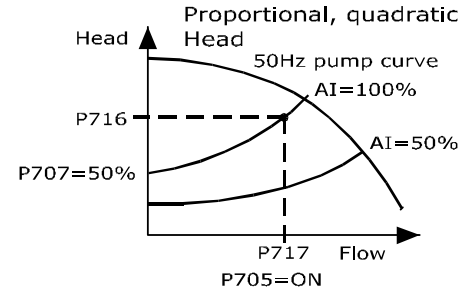
Function: The analog input can be used to reduce the user-defined head Q with a desired percentage. Using a 0-10 V potentiometer means that 0 V equals 0% and 10 V equals 100%. So if a 25% reduction is desired, set the potentiometer to 2.5 V.



175ZA917.10



175ZA918.10



175ZA919.10

■ Read-outs in LCP

In display line 1.1, 1.2 and 1.3 it is possible to read out the following:
Sensorless Head (very useful, if the user-defined Head is proportional)
Sensorless Flow
Sensorless Power, which is the actual power consumption of the system. It is recommended to use this read-out when measuring the pump characteristics. The value is filtered to make it more stable (Filter time constant FCM: 500 ms and VLT 6000: 4000 ms).

These choices can be programmed into the following parameters:

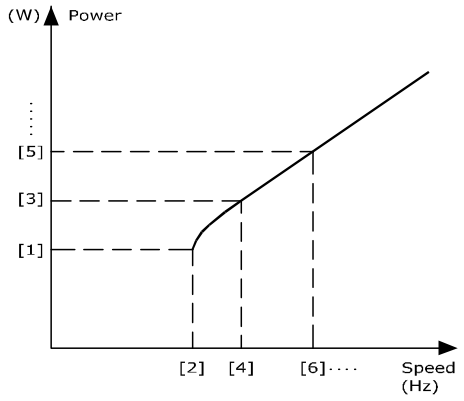
Functionality	Par. no. FCM	Par. no. VLT 6000
Large display read-out/Display line 2	009	007
Display line 1.1	010	008
Display line 1.2	011	009
Display line 1.3	012	010

The read-outs have the following numbers:

Choice	Choice no. FCM	Choice no. VLT 6000
Sensorless Power	[33]	[33]
Sensorless Flow	[34]	[34]
Sensorless Head	[35]	[35]

■ Power/Frequency Read-out

To enable the user to check if the calculated points used for control look right, Parameter 799 (PF READOUT) has been created. The parameter is indexed as read-only and contains 20 values: 10 points holding Power/frequency values. The values should develop like shown in the graph below:



175ZA928.10

All odd numbers show the power, and the even numbers show the frequencies. It is important for the control that:
[1] < [3] < [5] < [7] < [9] < [11] < [13] < [15] < [17] < [19] and
[2] < [4] < [6] < [8] < [10] < [12] < [14] < [16] < [18] < [20].

■ **VLT 6000**

Please note that the choice in parameter 300 "selection of MSB" has been removed, and consequently only 2 setups are available.

■ Measuring Values

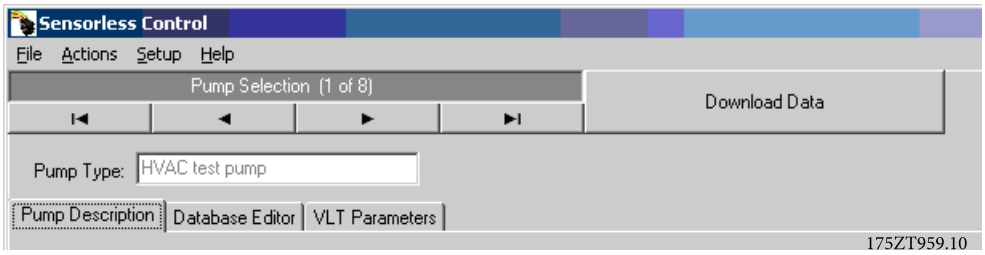
■ Introduction

This instruction concerns the use of SControl for Sensorless Pump Control for VLT 6000 and FCM 300. Please contact Danfoss to acquire the SControl Software.

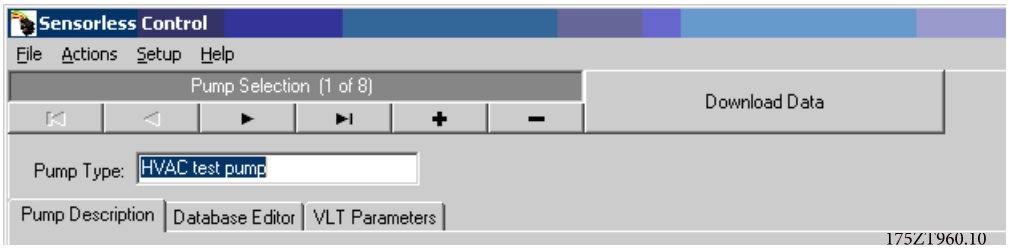
■ Installation and Setup of the Software

SControl operates in two modes:

- Production mode
  This mode is used in production in cases where pump data are not supposed to be changed. A pump can be chosen and data can be downloaded to the drive.



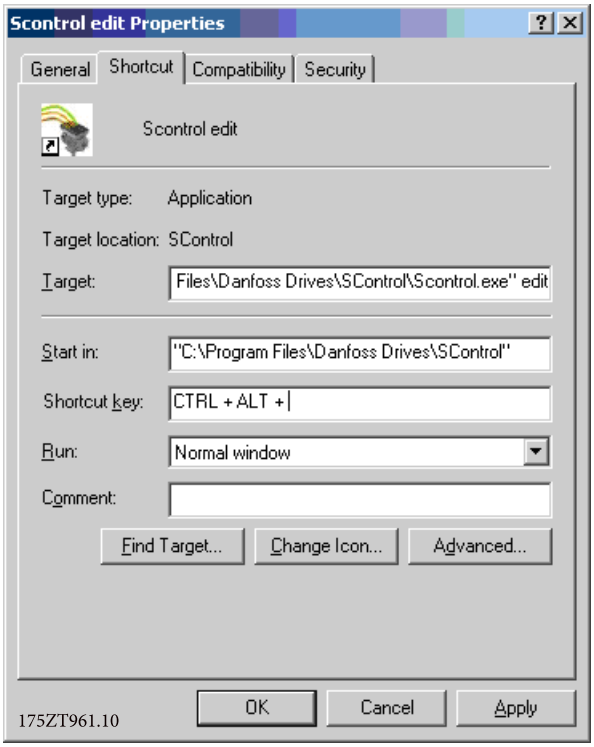
- Edit mode
  This mode is used when entering different pump data, adding and removing pumps. Also in this mode, data can be downloaded to the drive.



Please note that only the command buttons show which mode is active.

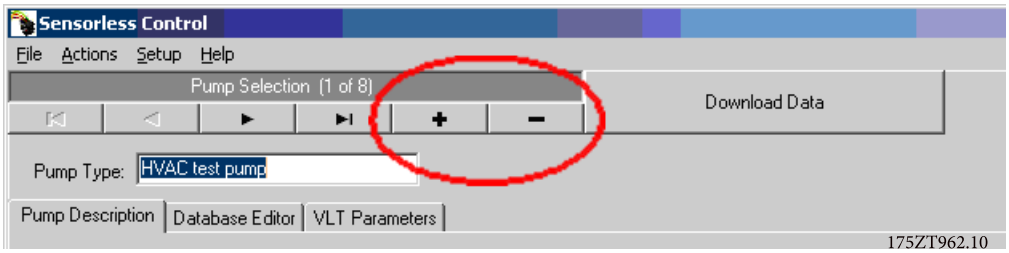
■ Installation

Run the "Setup.exe" file and the program will be installed. Only the Production Mode is installed in the first step. In order to install the Edit mode, create a short-cut of the program and type " edit" at the end of the path: "C:\Program Files\Danfoss Drives\SControl\Scontrol.exe" edit Remember to include a space before edit; otherwise it will not work.



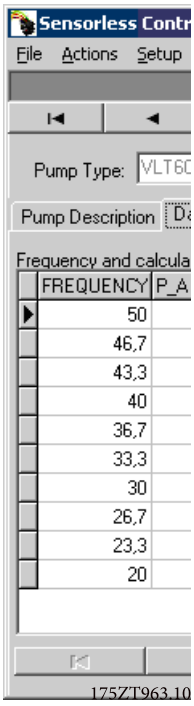
■ Entering Pump Data

To add a pump: Push the command button +
To remove a pump: Push the command button -

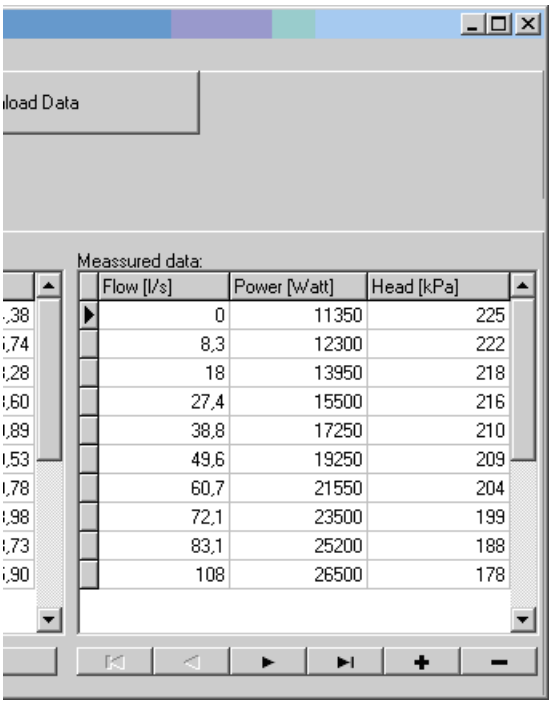


If the pump is connected to a VLT 6000, write VLT6*** in the pump type followed by the pump type.

For entering data, choose Database Editor.
Enter frequencies (one or more) in the left column. Start with the highest value. More frequencies can be added later.



Select one frequency and add flow/power/head values for that specific frequency. Start with no flow. It is important to have the same order as this:



■ Number of Measurements

The specified accuracy of Sensorless Pump Control (maximum 5% deviation) is based on having 100 measurements (10 frequencies and 10 flow/power and head measurements for each frequency). The minimum number is 16 measurements (flow/power/head values) for at least 4 frequencies.

The program also has a functionality called "Auto Insert Data". It is only necessary to use this functionality with 10 measurements for 1 frequency, and the program will calculate the remaining points.

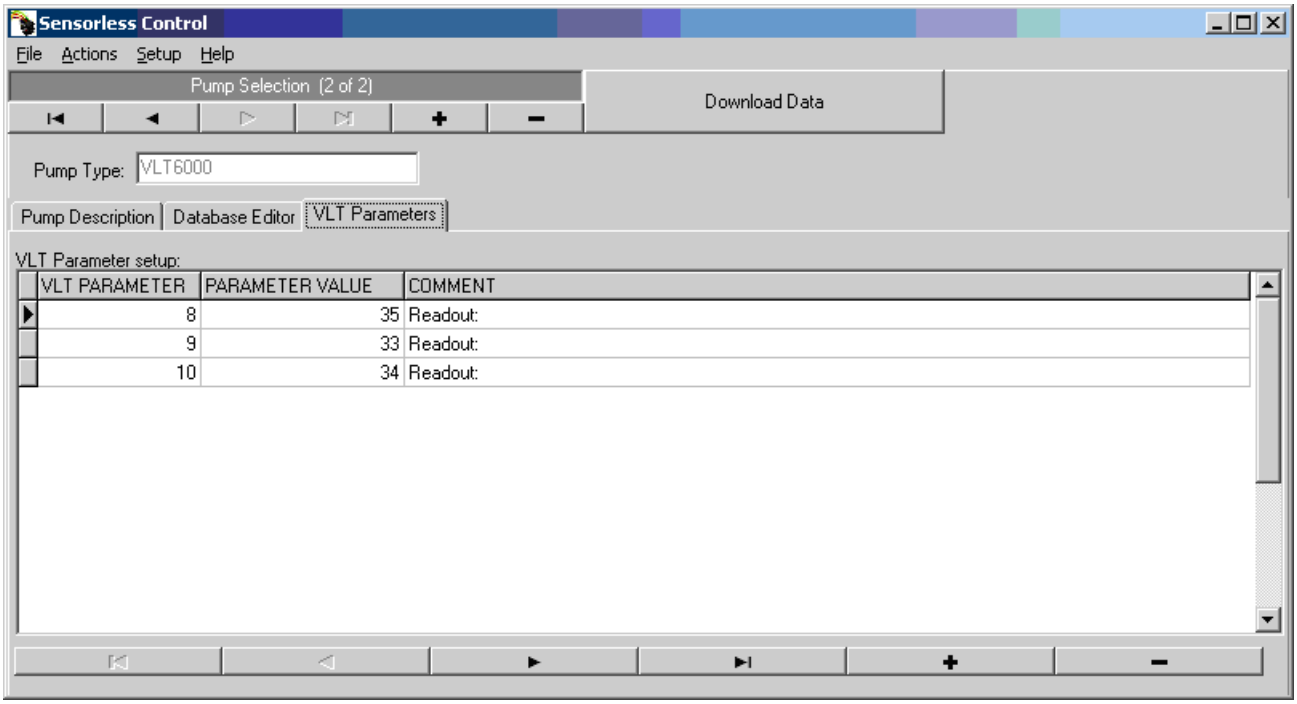
Please note that using less than 100 measurements will decrease the accuracy. Therefore check the accuracy after programming and make sure that it is within an acceptable level.

Step by step

1. Put the drive at fixed speed.
2. Find max flow (do not write it into SControl)
3. Measure Power/Head at 0 flow, write data in SControl.
4. Spread the flow measurements evenly in 10 steps, from 0 to max flow, and enter Power/Head/Flow values into SControl (see example above).
5. Do the measurements for 10 frequency steps evenly spread between Fmax and Fmin (unless using less than 100 measurements as described above).

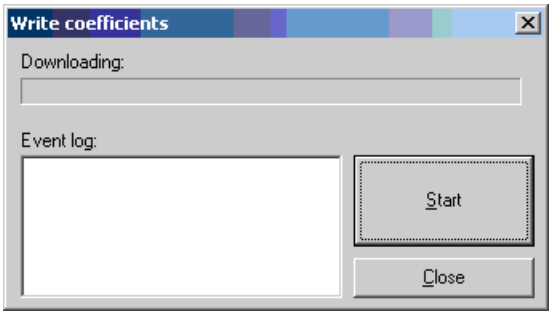
■ Other Functionalities of the Program

Pressing the "VLT parameters" command button, you can enter desired values for parameters. When downloading data to the drive, the listed parameters will be changed according to the entered values. The default setting of these parameters can be changed in "Setup" and "Default VLT Parameter Setting".



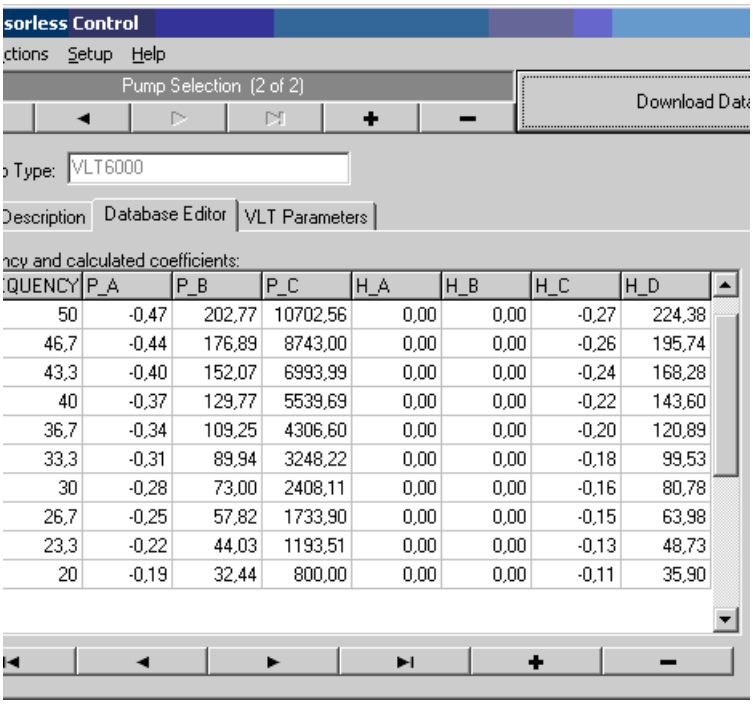
NOTE: The parameters in FCM and VLT 6000 HVAC are different, so it is not possible to make a general list.

Pressing the "Download Data" and "Start" button will start downloading of pump data and parameter settings into the drive.



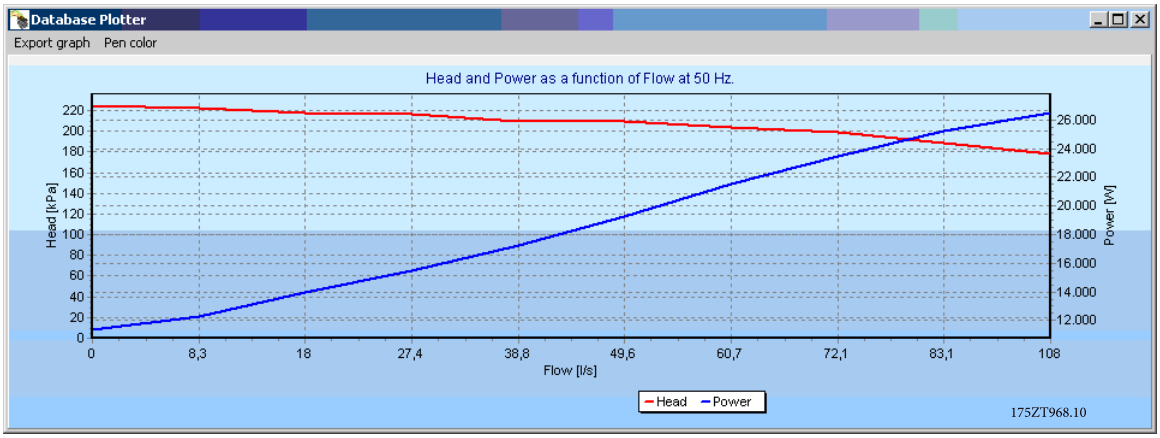
■ Data and Read-outs

The information on the left (P_A, P_B…) is in fact the coefficients to HEAD/FLOW and POWER/FLOW curves:
$H = f(Q) = aQ^3 + bQ^2 + cQ + d$
$P = f(Q) = aQ^2 + bQ + c$

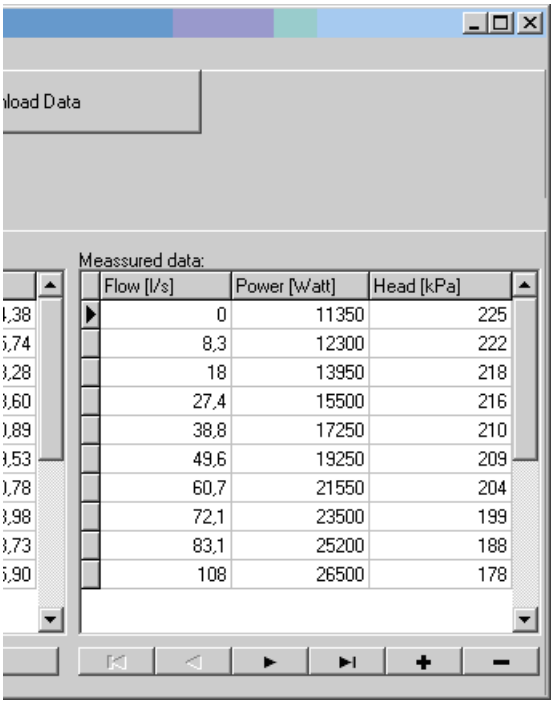


QUENCY	P_A	P_B	P_C	H_A	H_B	H_C	H_D
50	-0,47	202,77	10702,56	0,00	0,00	-0,27	224,38
46,7	-0,44	176,89	8743,00	0,00	0,00	-0,26	195,74
43,3	-0,40	152,07	6993,99	0,00	0,00	-0,24	168,28
40	-0,37	129,77	5539,69	0,00	0,00	-0,22	143,60
36,7	-0,34	109,25	4306,60	0,00	0,00	-0,20	120,89
33,3	-0,31	89,94	3248,22	0,00	0,00	-0,18	99,53
30	-0,28	73,00	2408,11	0,00	0,00	-0,16	80,78
26,7	-0,25	57,82	1733,90	0,00	0,00	-0,15	63,98
23,3	-0,22	44,03	1193,51	0,00	0,00	-0,13	48,73
20	-0,19	32,44	800,00	0,00	0,00	-0,11	35,90

The feature "DB plotter" in "Actions" can give a graphical overview of data measured at one frequency at a time:



This graph displays these data:



Flow [l/s]	Power [Watt]	Head [kPa]
0	11350	225
8,3	12300	222
18	13950	218
27,4	15500	216
38,8	17250	210
49,6	19250	209
60,7	21550	204
72,1	23500	199
83,1	25200	188
108	26500	178

If more data have been entered for other frequencies, simply select the other frequency without closing the plotter window.

Use "Export to Excel" to copy all data to the Excel sheet that comes with the installation of Scontrol: Open the Excel sheet "Sensorless Plot" and place the marker at cell A1, and choose "Edit" and "Paste".