1 Sensorless Pump Control

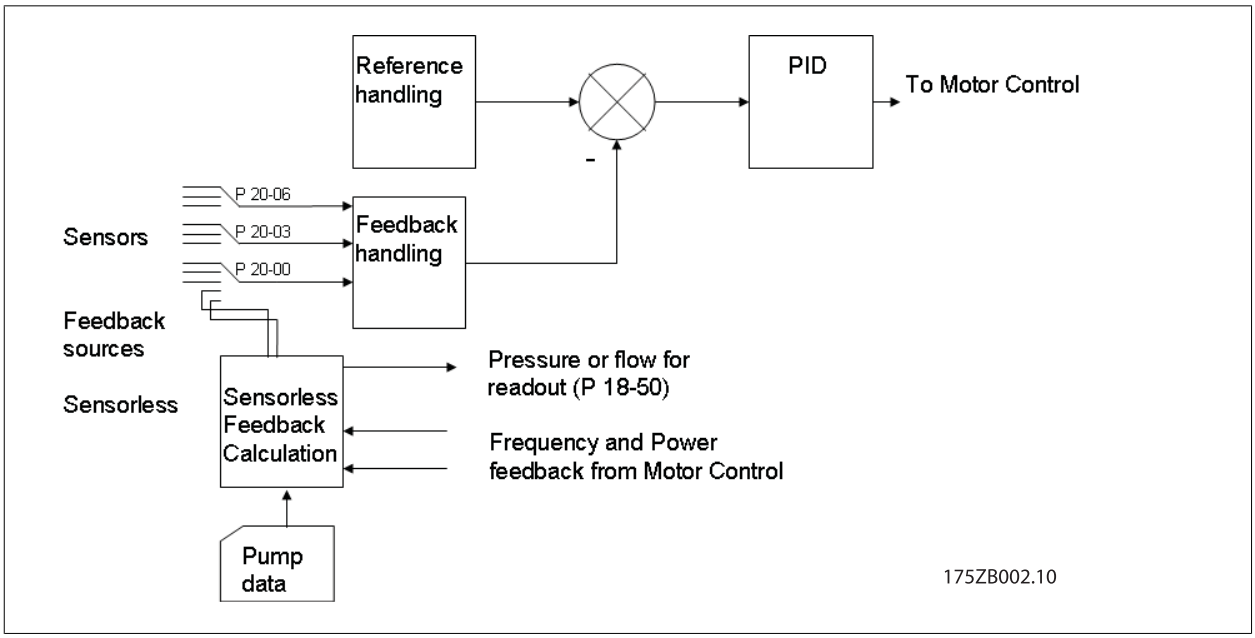
1.1.1 Introduction

Sensorless Pump Control (Sensorless) has been developed to enable the drive to control the pressure (Head) or flow in a circuit with non-compressible liquid, e.g. water, WITHOUT using a pressure transducer. This has several advantages such as:
The sensorless function can estimate either flow or pressure or both depending on what data has been loaded into the drive.

- 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.

1.1.2 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 graphs below show an example of some measured values for power/head and power/flow on a typical centrifugal pump.

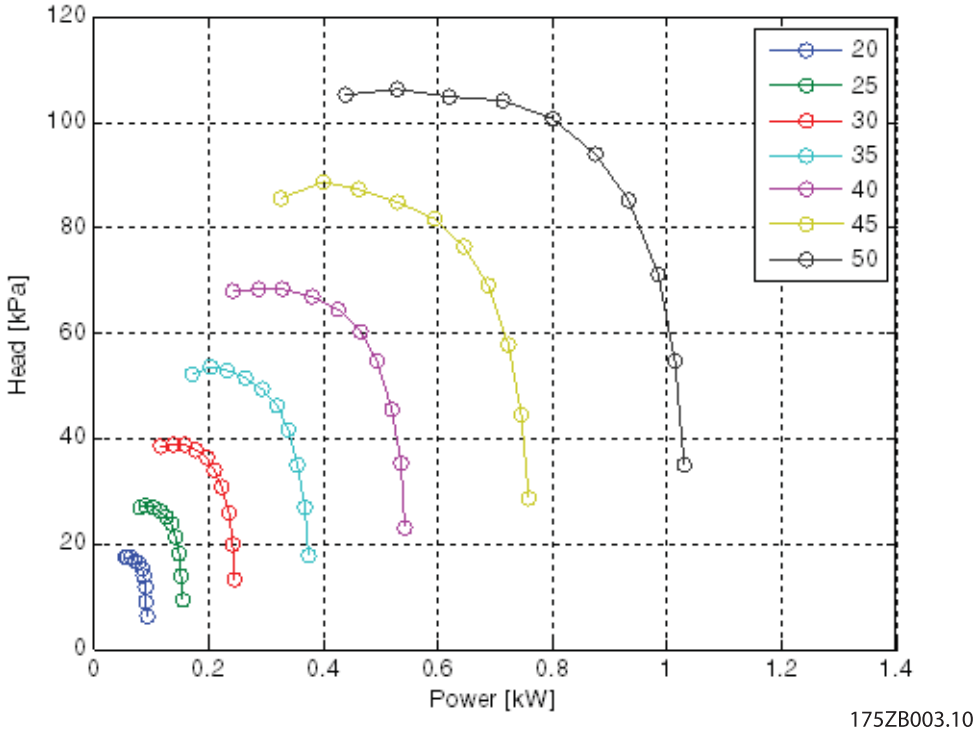


Illustration 1.1: Power/flow Curves for different frequencies on a 1.5 kW pump.

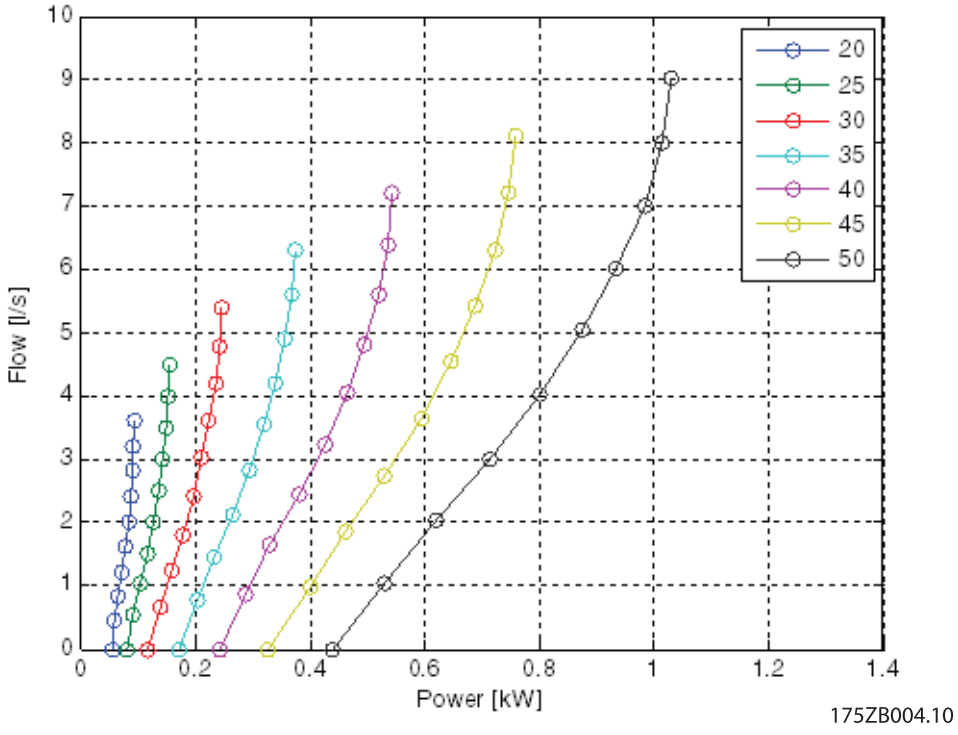


Illustration 1.2: Power/head Curves on a 1.5 kW pump.

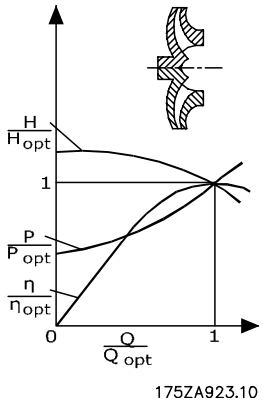
With these relations it is now possible to control the pressure or flow (e.g. keeping it constant if that is desired) by controlling the frequency according to the power measurement.

To control the pressure or flow it is necessary to use the closed loop PID controller of the drive. The tuning of the controller is recommended to be done manually, since the special application that a pump is, requires special settings of the PID controller. It is recommended to run the controller as close to a pure Integral controller as possible. That means decreasing the proportional gain to a very low value, sometimes close to zero. The differentiation time should not used. The response time of the system is then controlled by adjusting the Integral time down until an acceptable response time has been achieved. The lower the integral time, the faster the response, but also lower stability. To ensure stable operation in all operating points it is necessary to tune the PI controller with the valves of the system as open as they will ever be. It is though important that the flow is within the operating range when tuning the controller.

1.1.3 Limitations

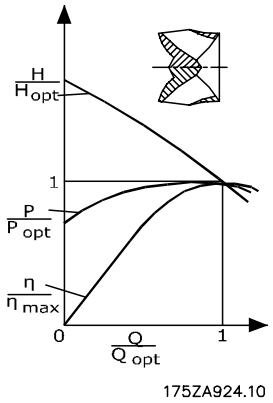
A criteria for Sensorless to work is that there must be a clear one-to-one relation between power and flow, (i.e. only one P-value to one Q-value and opposite).

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 can not 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.



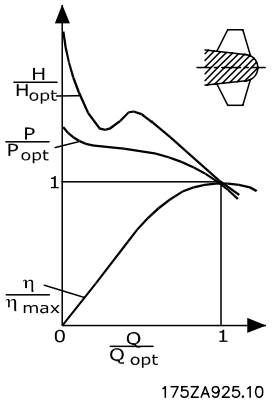
175ZA923.10

Radial impeller
n q=20 min -1
Possible



175ZA924.10

Mixed flow impeller
n q=80 min -1
Limited



175ZA925.10

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.

Pump measurements and final operation should only be performed in Variable Torque Mode. Set parameter 1-03 to [1] Variable Torque.

In general parameters influencing the operation (power consumption) of the motor should not be changed from measuring mode to final operation (basic motor parameters, advanced motor parameters, switching pattern, and switching frequency etc.).

The flow compensation of the pressure set point is carried out as a separate function in the FC-102. See Chapter 3.20.7, in the programming guide for a description of flow compensation. The sensorless function can only estimate pressure and flow in the range that data has been loaded into the drive. That means that if a flow range of 0-100 m3/h has been measured at 50 Hz the maximum flow that can be estimated at this frequency is 100 m3/h. For lower frequencies the flow range will of course be smaller according to the affinity equations. The maximum flow at for example 25 Hz will therefore be 50 m3/h.

1

1.2 Parameters used for Sensorless Control

Refer to the standard FC-102 parameter for closed loop control for setting of the control dynamics (Parameter group 20) and flow compensation functions (Parameter Group 22-8*)

16-26 Power Filtered [kW]

Range:	Function:
	Motor power consumption. The value shown is calculated on basis of the actual motor voltage and motor current. The value is filtered, and a few seconds may pass from when an input value changes to when the data read-out values change.
0.000 kW* [0.000 - 10000.000 kW]	

16-27 Power Filtered [hp]

Range:	Function:
	Motor power in HP. The value shown is calculated on the basis of actual motor voltage and motor current. The value is filtered, and a few seconds may pass from when an input value changes to when the data read-out values change.
0.000 hp* [0.000 - 10000.000 hp]	

1.2.1 18-5* Reference and Feedback

Parameters for reporting the reference and feedback input.

18-50 Sensorless Readout [unit]

Range:	Function:
	View the pressure or flow resulting from the sensor-less calculations. This value is the value not used for control. The value will only be updated if sensor-less data supports both flow and pressure.
0.000 SensorlessUnit* [-999999.999 - 999999.999 SensorlessUnit]	

20-00 Feedback 1 Source	
Option:	**Function:**
	The effective feedback signal is made up of up to three different input signals. Select which drive input should be treated as the source of the first of these signals. The internal calculated signals for flow and pressure can also be selected. The other input signals are defined in par. 20-03 and 20-06.
[7]	Analog input X30/11
[8]	Analog input X30/12
[9]	Analog Input X42/1
[10]	Analog Input X42/3
[11]	Analog Input X42/5
[0]	No function
[1]	Analog input 53
[2] *	Analog input 54
[3]	Pulse input 29
[4]	Pulse input 33
[7]	Analog input X30/11
[8]	Analog input X30/12
[9]	Analog Input X42/1
[10]	Analog Input X42/3
[11]	Analog Input X42/5
[100]	Bus feedback 1
[101]	Bus feedback 2
[102]	Bus feedback 3
[104]	Sensorless Flow
[105]	Sensorless Pressure

NB!
If a feedback is not used, its source must be set to *No Function* [0]. Par. 20-20 *Feedback Function* determines how the three possible feedbacks will be used by the PID Controller.

1.2.2 20-6* Sensorless

Parameters for Sensorless. See also par. 20-00, 18-50, 16-26 and 16-27.

20-60 Sensorless Unit	
Option:	**Function:**
	Select the unit to be used with par. 18-50 Sensorless Readout.
[20]	l/s
[21]	l/min
[22]	l/h
[23]	m³/s
[24]	m³/min
[25]	m³/h
[70]	mbar
[71]	bar
[72]	Pa
[73]	kPa

1

[74]	m WG
[75]	mm Hg
[120]	GPM
[121]	gal/s
[122]	gal/min
[123]	gal/h
[124]	CFM
[125]	ft³/s
[126]	ft³/min
[127]	ft³/h
[170]	psi
[171]	lb/in²
[172]	in WG
[173]	ft WG
[174]	in Hg

20-69 Sensorless Information

Range:

Function:

View information about the sensor-less data.

0 N/A*	[0 - 0 N/A]

1

1.3 PC Software for managing Pump Data

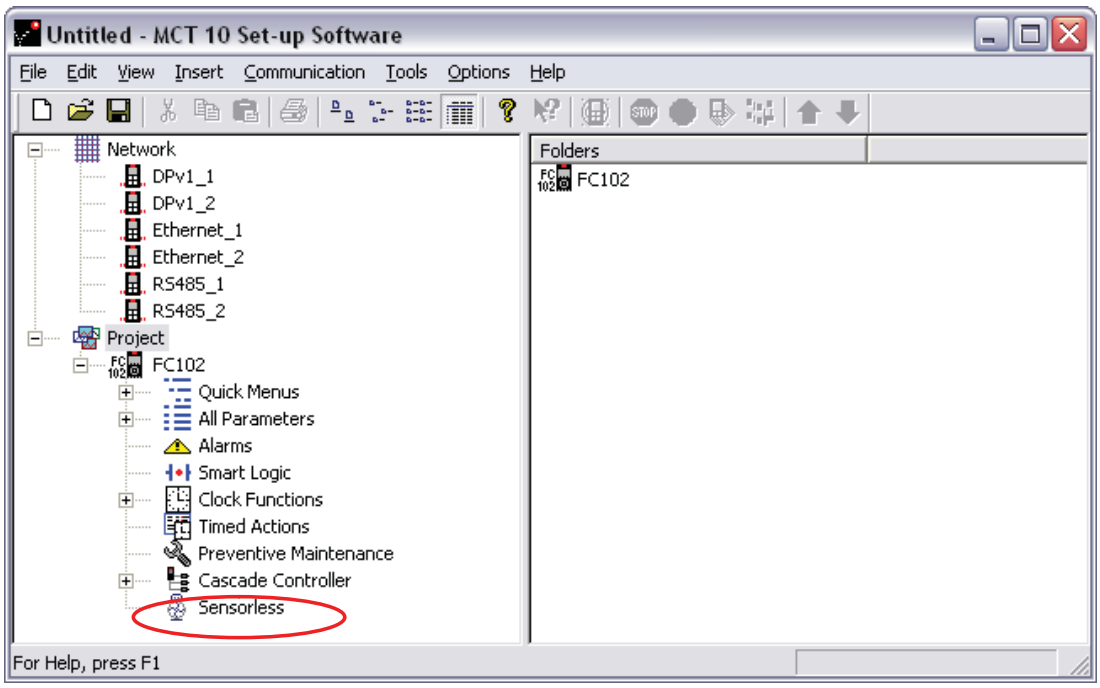
MCT10 Setup Software is the tool used for connectivity to all Danfoss Drives frequency converters. It is designed as a project orientated interactive application providing capabilities for quickly and easy commissioning.

With MCT10 Setup Software the user is able to control and configure the system simultaneously, monitor the system effectively for faster diagnosis and better preventive maintenance, simplify commissioning, maintenance and documentation.

The MCT10 Setup Software can in general be used as follows:

- Visualization of the functionalities supported in the frequency converter(s).
- Connectivity to frequency converter(s) using flexible fieldbus support.
- Planning a new communication network off-line. The MCT 10 Setup Software contains a complete database with all Danfoss Drives products.
- Commissioning a single or a network of frequency converters online.
- Backup of all parameter settings of a single or a network of frequency converters.
- Expand a network with more frequency converters.
- If a frequency converter requires replacement.
- Setup a frequency converter using Sensorless pump control. A special CD-key is required, please contact Danfoss.

The MCT10 Setup Software is the tool used for configuring a frequency converter to control the pressure or flow in a circuit with non-compressible liquid without using a pressure transducer. The functionality is available from a plug-in in MCT10 only for the FC102 (HVAC) and FC202 (AQUA) drives.



The Sensorless plug-in is only available if the drive firmware supports Sensorless pump control. Either flow, pressure or both can be written to the frequency converter.

1

The Sensorless plug-in provides the following functionalities.

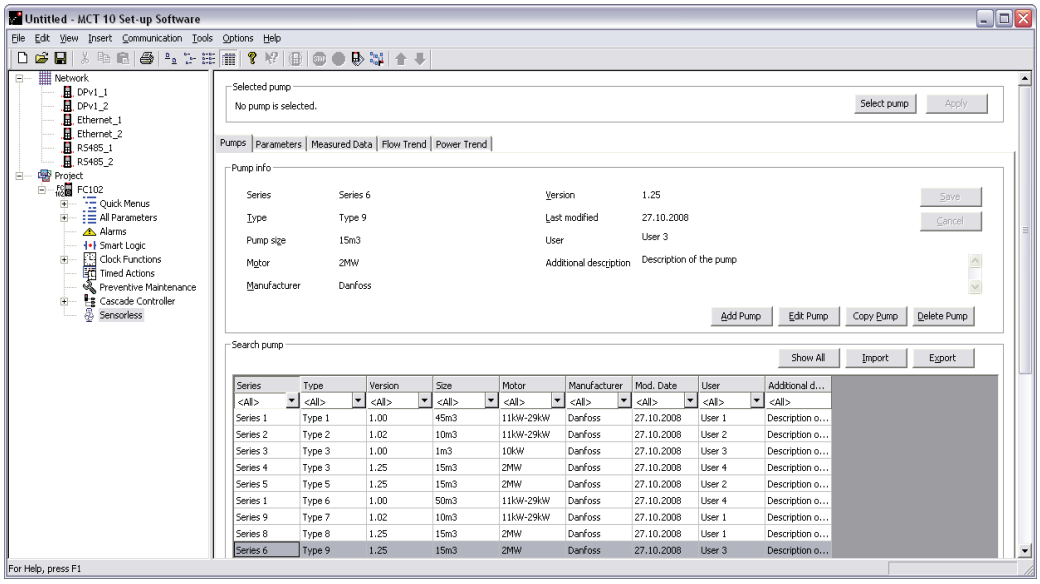
- Measure either flow, pressure or both.
- Flexible measuring configuration.
- Visualization of the measured data.
- Visualize the calculated data the frequency converter will use for controlling the pump.
- Store the measured data into a pump database.
- Create new pumps.
- Flexible database management
- View the specific Sensorless parameters
- Download Sensorless pump data to the drive.

The Sensorless functionalities provided are divided into five tabs named Pumps, Parameters, Measured Data, Flow Trend and Power Trend respectively.

1.3.1 Pumps

In the Pumps tab the user have access the Sensorless pump database. It contains specifically for each pump the pump info, the specific pump data and the associated parameters. Each pump is described with a pump information:

- Series
- Type
- Pump size
- Motor
- Manufactor
- Version
- Last modified
- User
- Additional description

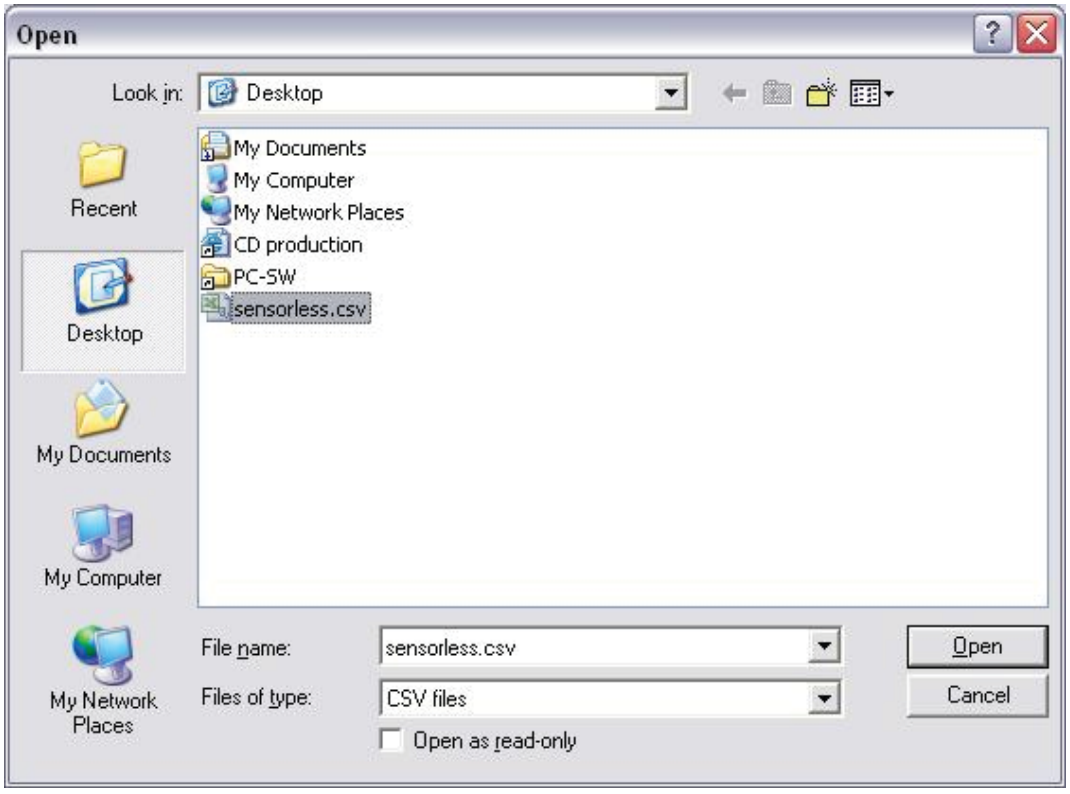


175ZB006.10

The database is available from the table containing the Pump info. The user can scroll down or search according to the Pump info from the Search pump drop down menus. A single or a combination of search criteria's can be selected. The Show all bottom refresh the table with the pumps available in the database.

The pump database can be distributed in a csv file format between several MCT10 Setup Software installations using the Import and Export bottoms. The csv file format is described in the Appendix.

From the Import file dialog a pump database can be restored, extended or partly updated. The location can be specified locally or from a network path.



175ZB007.10

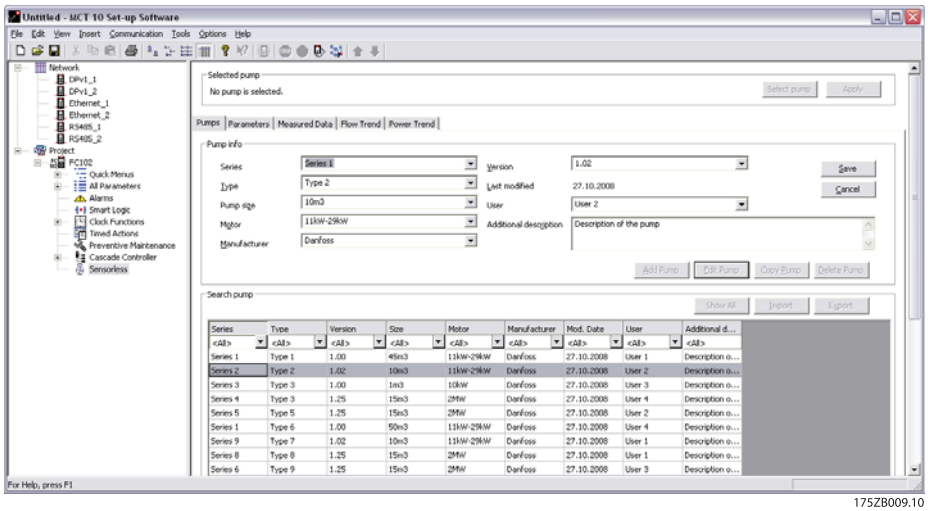
From the Export dialog three criteria's are available

- **All**, export the complete pump database.
- • **Filtering content**, export the pump(s) listed from a search criteria.
- • **Updated**, exports the pump(s) updated within a time period.

175ZB008.10

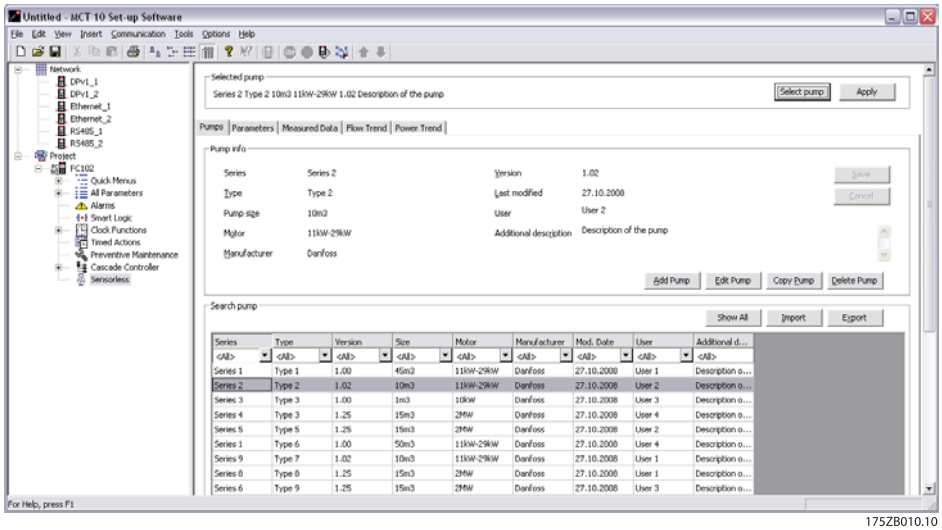
1

There are several ways editing the database. Pumps can be added or deleted, existing ones can be copied or renamed. While editing all pump information except Last modified will be reconfigurable. All changes is updated from the Save bottom. Cancel discards the Pump info editing mode and returns to display the Pump info.



175ZB009.10

Per default no pump is selected and no data will be available from the Parameter, Measured Data, Flow Trend and Power Trend tab. It is required the user to mark the specific pump from the database and to press the Select pump bottom. The pump description is then listed as the selected pump.
It is not possible to delete a selected pump.

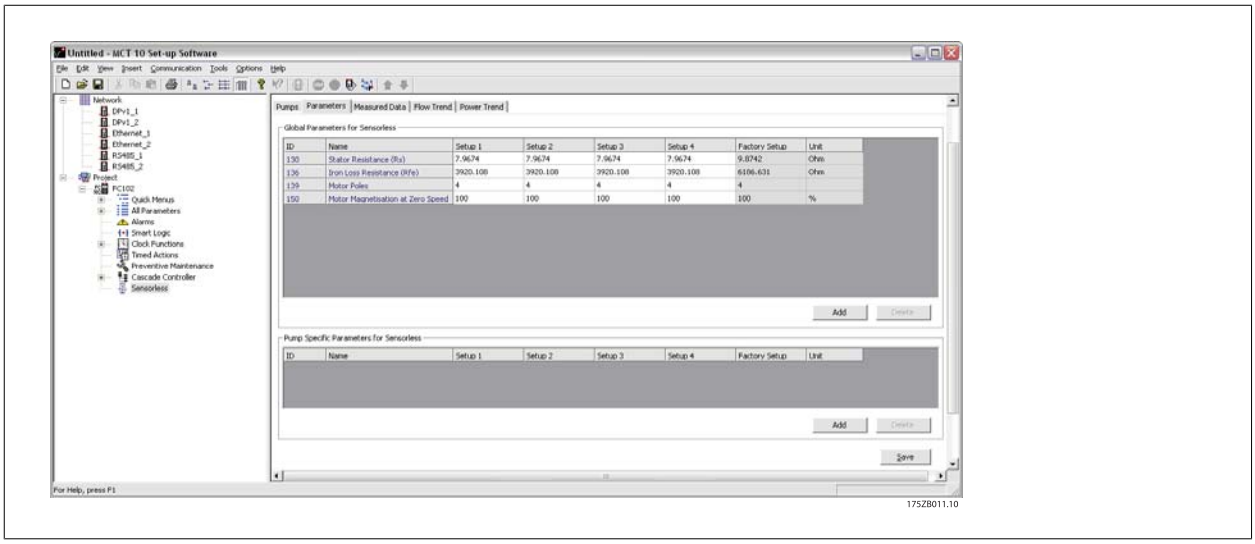


175ZB010.10

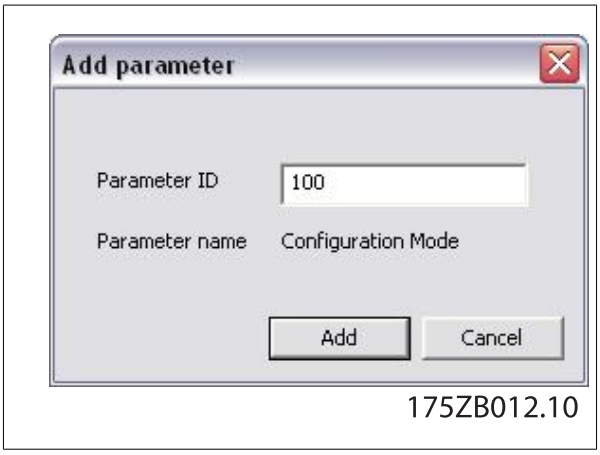
The selected pump data is written to the frequency converter using the Apply button if a frequency converter is online connected. If no frequency converter is online connected, data will be only applied to the MCT 10 project file.

1.3.2 Parameters

Sensorless specific parameters can with advantage be placed in the Parameters tab to simplify configuration. It is divided into a Global and Pump Specific list. Global parameters are stored centrally in the database and apply to all pumps. Pump Specific parameters applies only to the pump selected. Copying a pump from the Pump tab also copies the Pump Specific parameters.



Both lists can be updated using the Add or Delete buttons. Only the parameter ID is required adding parameter to one of the lists. When a valid ID is entered, the corresponding Parameter name will be displayed.



A parameter can be removed from lists using one of the Delete buttons. All parameters changes made is applied to the database with the Save bottom. Parameter changes are downloaded to the drive with the Apply button. If no frequency converter is online connected, parameters will be only applied to the MCT 10 project file.

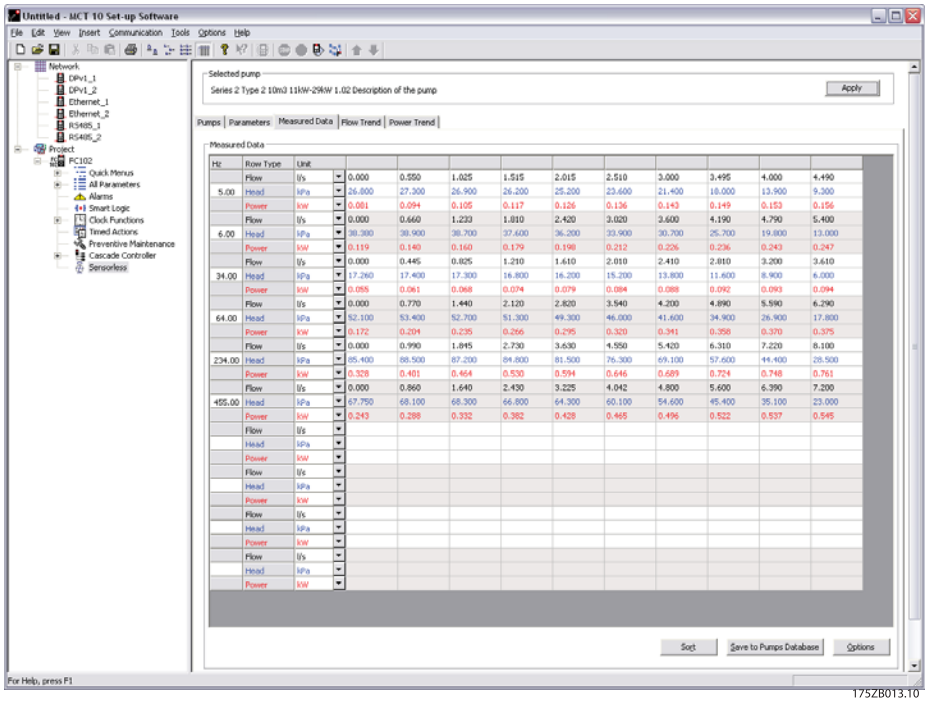
1.3.3 Measured Data

The Measured Data tab contains the coefficients for head, flow and power to be used in the frequency converter. It is based on a 10x10 matrix with maximum 10 frequencies and 10 points per frequency.
The minimum inputs required to calculate the polynomials is:

- Four data points in the same frequency.
- One data point in another frequency.

Measuring a pump (pressure/flow/power) it is important to find the flow rate which has the highest power and use this as the maximum measured value of pressure and flow. If measurements are carried out at higher flow rates which have lower power, the measurements will be invalid and algorithm cannot estimate correctly.

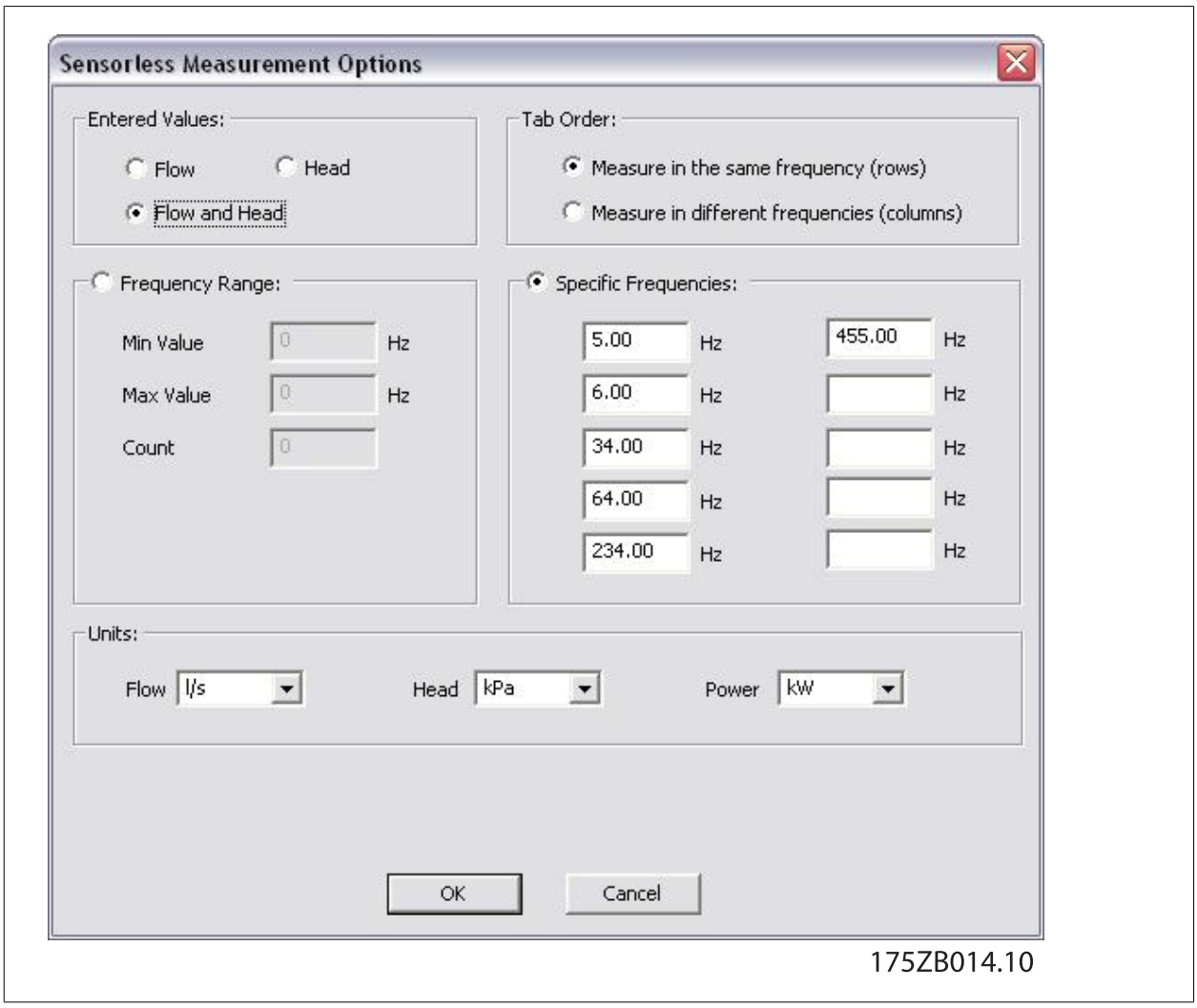
If a selected pump contains measured data the coefficients will be listed. The content is depending on the pump measuring option.



175ZB013.10

A selected pump without containing any measured data can be measured in on- or offline. Online the power data will automatically be read from the connected frequency converter. Offline the user will have to manually enter the power data.

The measuring preconditions is configured from the Options bottom.



Entered Values, the user can setup measure using flow, head or both.

Tab Order, setup the principle of measure. Measuring in the same frequency the power is measured adjusting the flow, head or both. Measuring in different frequencies the flow, head or both is constant, measuring the power by adjusting the frequency.

Frequency, the user can setup using a frequency range with a linear interval or using up to 10 specific frequencies.

Units, setup the engineering unit for Flow, Head and Power. Similar setup is available from the Measured Data Unit drop down menus.

From the Sort button the user can sort according to flow, head or power. The measured data is stored in the database with the bottom named Save to Pumps Database.

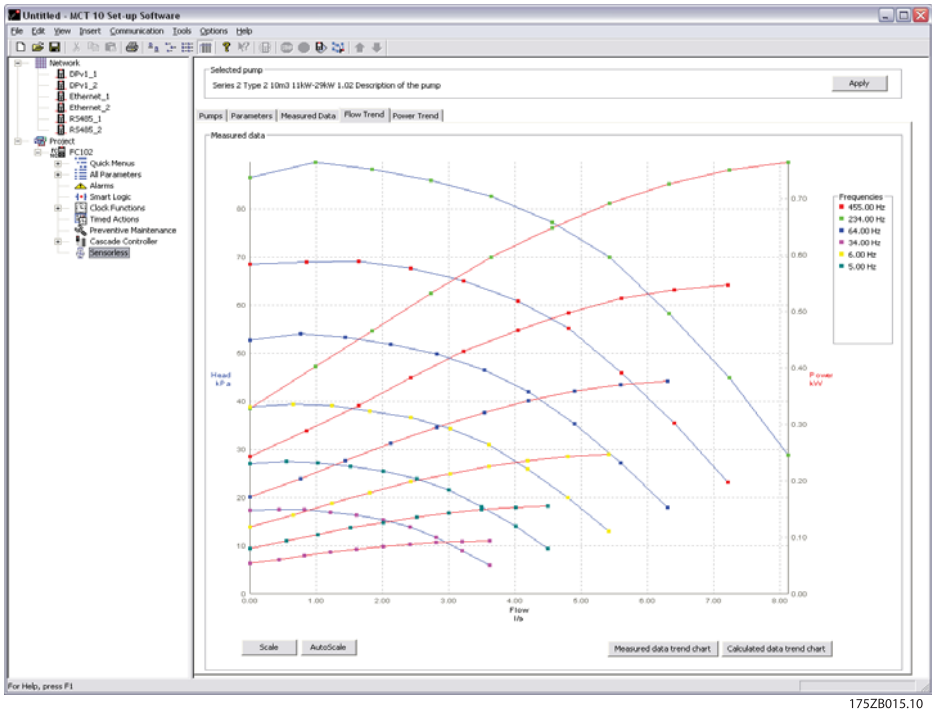
The coefficients are downloaded to the drive with the Apply button. If no frequency converter is online connected, the coefficients will only be applied to the MCT10 project file.

1.3.4 Trend Charts

Two trend tabs flow and power are available to verify the measured data. Pump data is applied from the Apply button similar to the Pump tab.

1.3.5 Flow

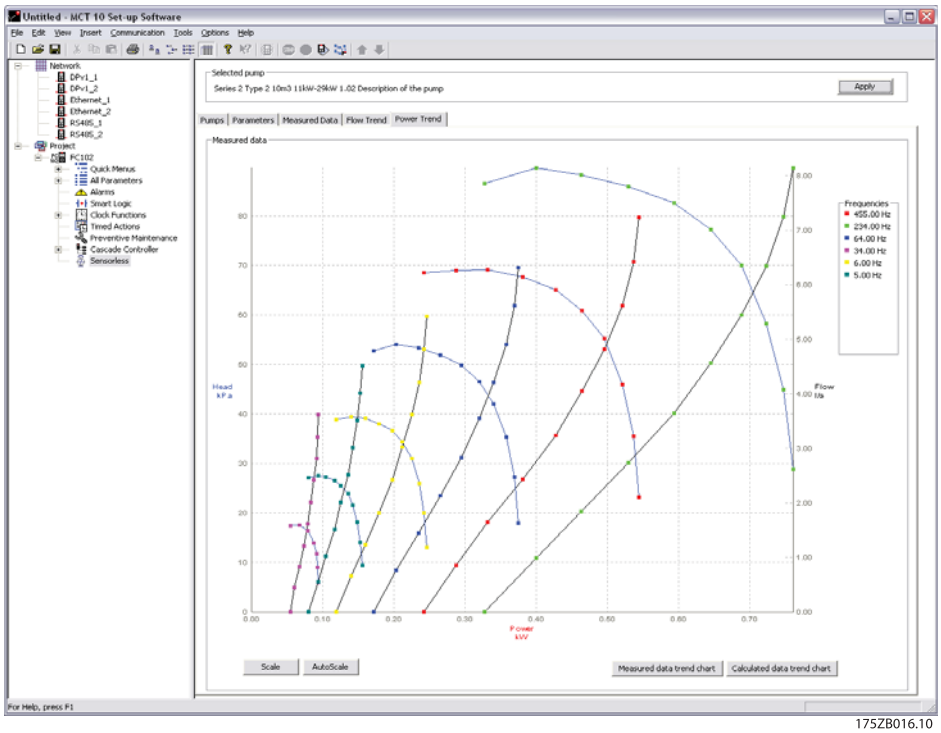
The Flow tab visualizes the measured polynomials for head versus flow and power versus flow. They are colour coded according to the frequency.



175ZB015.10

1.3.6 Power

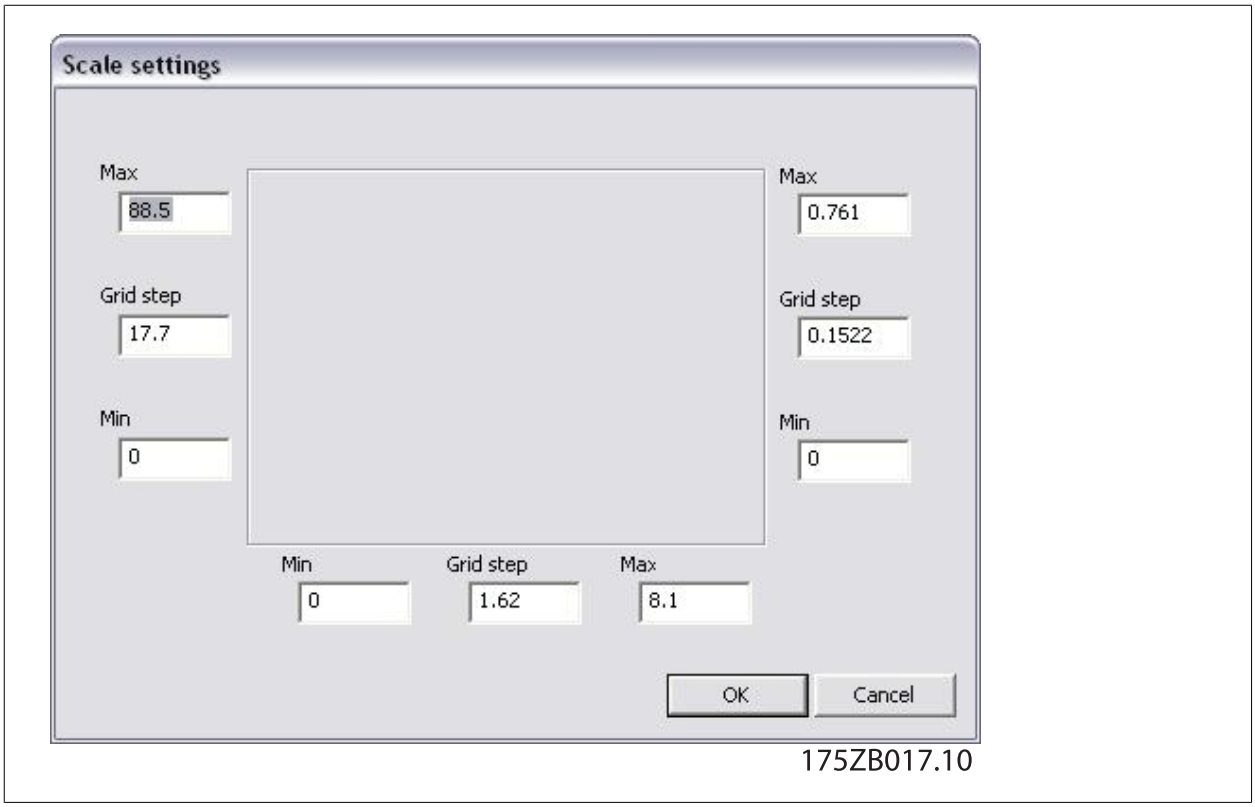
The Power tab visualizes the measured polynomials for head versus power and flow versus power. They are colour coded according to the frequency.



175ZB016.10

1.3.7 Scaling

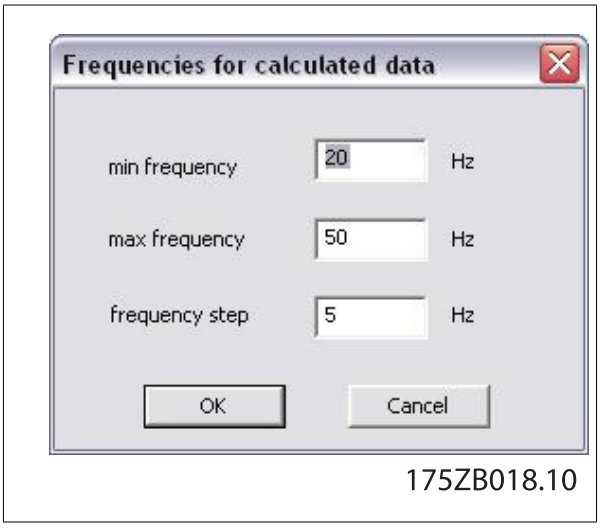
The trend charts are per default autoscaled according to the maximum value. A Scale bottom provides the possibility to reconfigure the resolution zooming in or out anywhere on the graph by setting up the three axes individually with a minimum and maximum value. The Grid step defines the size between the grid lines.



A trend chart is restored to default scale settings with the AutoScale button.

1.3.8 Calculated Data

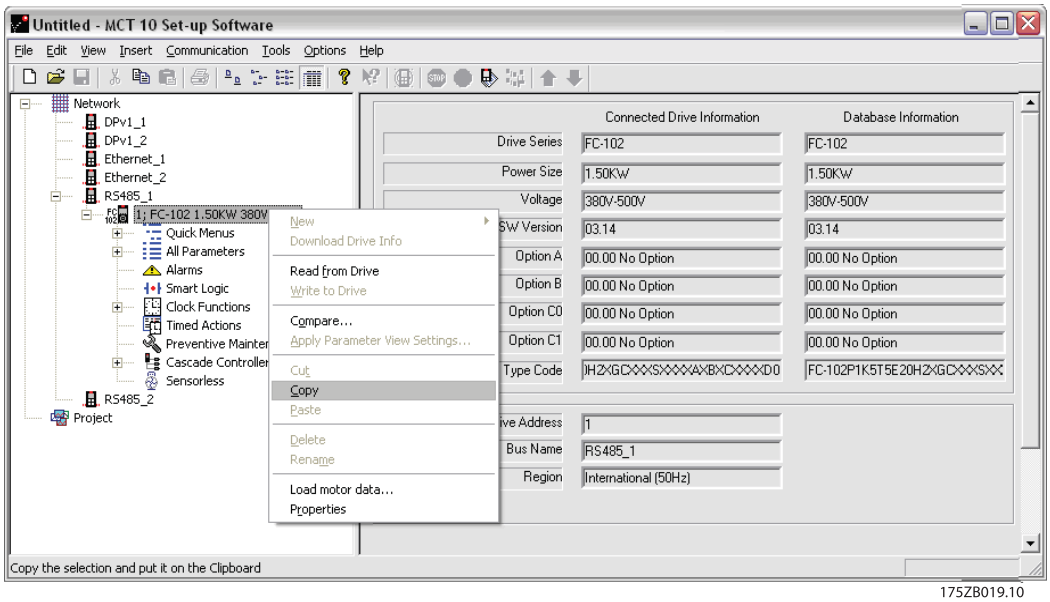
With the Calculated data trend chart bottom the user can simulate the polynomials similar to the ones calculated and used within the frequency converter by setting up the minimum and maximum frequency. The frequency step defines the size between each polynomial. Reducing the frequency step size increases the number of polynomials displayed.



1

1.3.9 Copy/Paste Sensorless Data to Offline

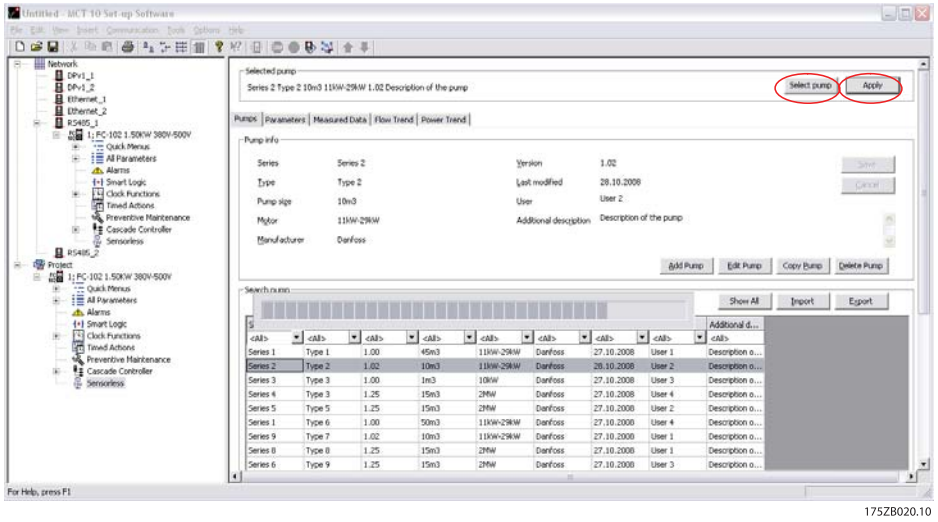
Reading the Sensorless related information from the frequency converter follows the standard MCT 10 procedure copy/paste an online drive to offline. Right click on the specific drive and choose Copy. Then right click on Project and paste to offline.



1.3.10 Write Sensorless Data to Drive

Applying the pump data to an online frequency converter terminates the drive application and activates the boot mode. The boot mode is a standard functionality within the frequency converter to update the firmware and Sensorless pump data. While the drive is in boot mode it will not be possible to establish connectivity from other MCT 10 applications. When pump data is successfully written to drive the boot mode is terminated and a restart is initiated.

Pump data can be applied from the Sensorless plugin or by writing to drive traditionally. If a pump is selected the pump data is always downloaded when writing to drive.



1.3.11 Appendix CSV File Format

The file used to distribute the Sensorless pump database between MCT 10 installations is based on a standard comma separated file format (*.csv). With a csv file format the user can easily adapt between several pump database formats and import into MCT 10.

Importing or exporting data from the MCT 10, the data is stored in a single CSV file. This CSV file is divided into three sections: pumps, data points and parameters. The parameters section is optional.

1.3.12 General Structure of the CSV Files

The file begins with a header that describes the fields present in the file followed by a number of records. The records are separated by new-line characters. Each record consists of fields. The fields are separated by semicolon (;). There are 2 types of fields - text and numeric. Text fields are enclosed in double quotes ("), numeric fields are not. If a text field has a value that contains a double quote, then this character is escaped with two adjacent double quotes (""). The text field may contain any character (including new-line). If a numeric field contains a fractional value, then the whole part and fraction are separated by decimal point (.).

1.3.13 Pumps Section

This section contains the following fields:

Field Name	Type	Maximum Lenght	Description
10	Number		Record type identifier. This must be the first field in the record and its value must be 1 for all pump records.
Id	Number		Pump identifier. This number must be unique for each record in the file.
Series	Text	50	Pump Series
Version	Text	32	User-specified text to distinguish between pumps with different configuration.
Size	Text	50	Pump size.
Motor_power	Text	50	Pump power.
Manufacturer	Text	64	Name of the manufacturer of the pump.
Description	Text	256	Descriptive text about the pump.
Power_unit	Text	32	Physical unit that power is measured in and displayed in the Sensorless tool.
Head_unit	Text	32	Physical unit that head(pressure) is measured in and displayed in the Sensorless tool.
Flow_unit	Text	32	Physical unit that flow is measured in and displayed in the Sensorless tool.
Type	Text	50	Pump type.
User	Text	50	User name.

1.3.14 Data Points Section

This section contains the following fields:

Field Name	Type	Maximum Length	Description
20	number		Record type identifier. This must be the first field in the record and its value must be 2 for all data point records.
pump_id	number		ID of the pump this datapoint was measured for. This should be value that exists in one of the id fields in Pumps file.
frequency	number		Frequency at which the datapoint was measured (in Hz).
power	number		Power measured in units specified in the pump record's field power_unit.
head	number		Head measured in units specified in the pump record's field head_unit.
flow	number		Flow measured in units specified in the pump record's field flow_unit.

Flow and head values are not mandatory. To indicate that this value is missing, Not Available value should be used. This value can be indicated by any of the following values: NA, Na, na and -. These values must not be surrounded by quotes similar to text values. Negative values are not allowed for any field.

1.3.15 Parameters Section

This section contains the following fields:

Field Name	Type	Maximum Lenght	Destription
30	number		Record type identifier. This must be the first field in the record and its value must be 3 for all parameter records.
pump_id	number		ID of the pump this parameter belongs to.
parameter_number	text	10	Parameter number, e.g."0130", "001" etc. This is an MCT 10 specific parameter ID.
value	text	50	Parameter value. This can be of different formats, but we save it as a string.
setup_number	number		Usually there are four setups specified in MCT 10. Parameter values may differ indifferent setups