Application Note on Sensorless Pressure- or Flow Estimation

Introduction

This application note serves as a guide to the build-in features for estimating either flow or pressure in pump applications with the VLT HVAC Drive. It provides an easy-to-follow guide to commissioning the sensorless estimation features and explains advantages and limitations of two different estimation methods.

The target group includes customers, installers, support technicians, application engineers and marketing.

Why Estimate Flow or Pressure?

Estimating either flow or pressure has three main advantages over utilizing feedback from equivalent transducers (flow meter or manometer):

1. Reduced purchase cost of the system by saving the cost of the transducer (flow or pressure).
2. Reduced installment costs (less mechanical components to install/simpler system).
3. Reduced maintenance costs due to less transducers requiring ongoing maintenance due to calibration or wear.

The VLT HVAC Drive provides two options for sensorless estimation:

1. Sensorless Pump Control: This method is described in greater detail in Application Note MI90C102. This option makes it possible to make a pump track either an output flow or pressure reference, based on a feedback from the estimation algorithm.
2. Sensorless Estimation Readout: This option is elaborated in this note. This option is not conflicting with option 1, but can, besides sensorless control also be utilized as a replacement for either conventional flowmeter or manometer. Possibilities for readout include LCP and standard bus / MCT-10.

Two Approaches for Sensorless Estimation

When focusing on the sensorless estimation of either flow or pressure the user has two possibilities for estimation.

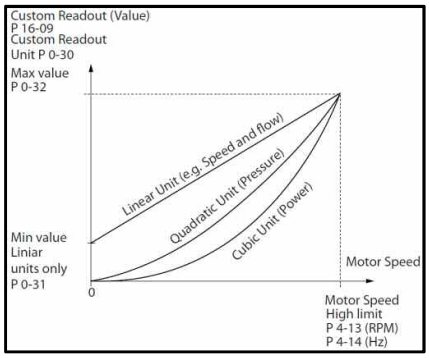
The first is the 'Custom Readout', which provides an easy to commission flow or pressure estimation for simple, and static systems (here static refers to a non-changing speed-load curve, which e.g. is characteristic for systems without valves that opens/closes).

The second approach is the sensorless flow or pressure estimation algorithm which is an advanced method that can handle changes in the speed-load curve including opening and closing of valves.

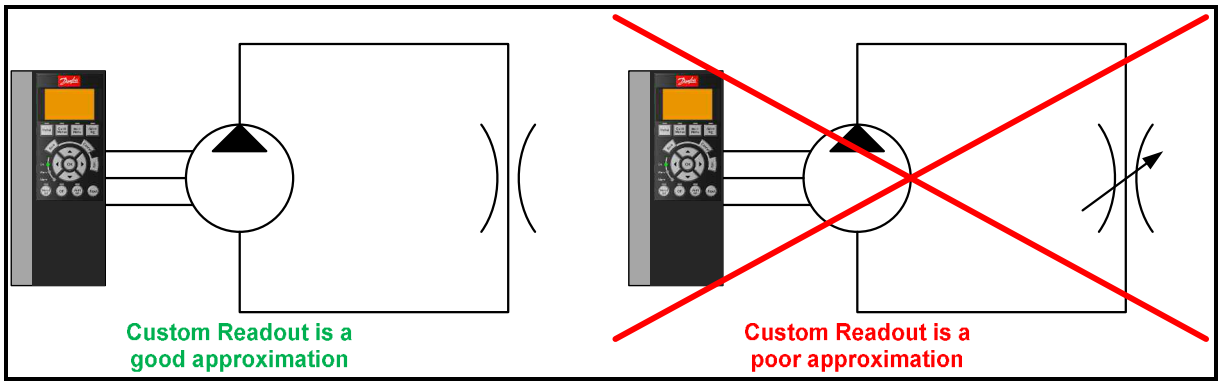
The following two subsections explain each of these approaches in greater detail.

Sensorless Estimation Using Custom Readout

The custom readout method is based on the assumption of a linear (flow) or quadratic (pressure) dependency on motor speed (cf. Figure below).



These assumptions are valid as long as the load profile remains unchanged. In practice this means that the method is primarily suited for systems without valves with variable opening, (see figure below):

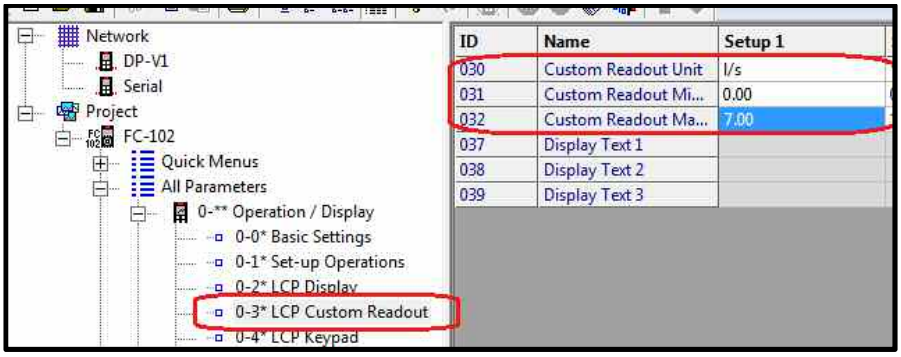


Step-by-step Guide for Custom Readout

The following step-by-step-guide describes how to setup custom readout for either pressure or flow readout:

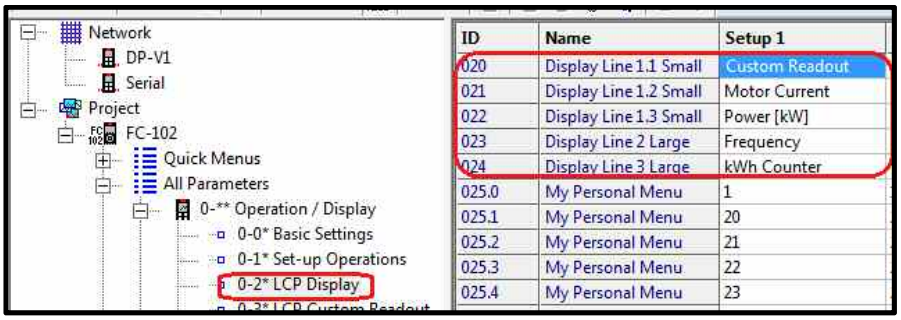
First step is to select which custom readout to show:

- Par. 0-30 'Custom Readout Unit': Choose a unit of either pressure or flow, e.g. kPa (pressure) or l/min (flow).
- Par. 0-31 'Custom Readout Min Value': Enter the minimal value of the pressure/flow. Typically 0l/min for flow and pressure at zero speed for pressure.
- Par. 0-32 'Custom Readout Max': Enter the flow/pressure at maximal output frequency (typically at 50Hz). The best way to obtain this number is to make a full speed measurement of either speed or flow on the system during commissioning. This is not always possible and could thus rule out this as an option for flow/pressure estimation. In these cases it is recommended to use the sensorless estimation algorithm.

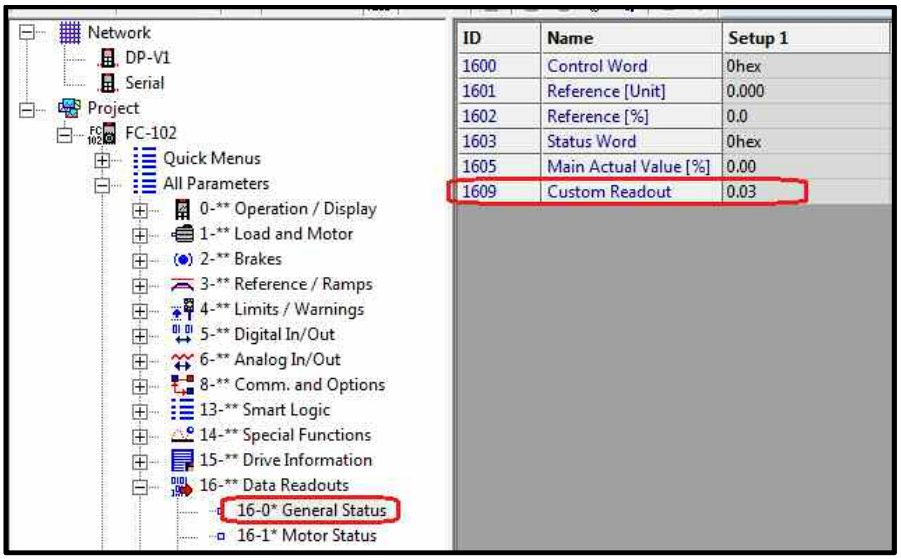


The next step is to read out the 'Custom Readout' in LCP or MCT-10.

- For read out in LCP set either of par. 0-20 through 0-24 to 'Custom Readout'.



- For readout in MCT-10 use par.16-09.

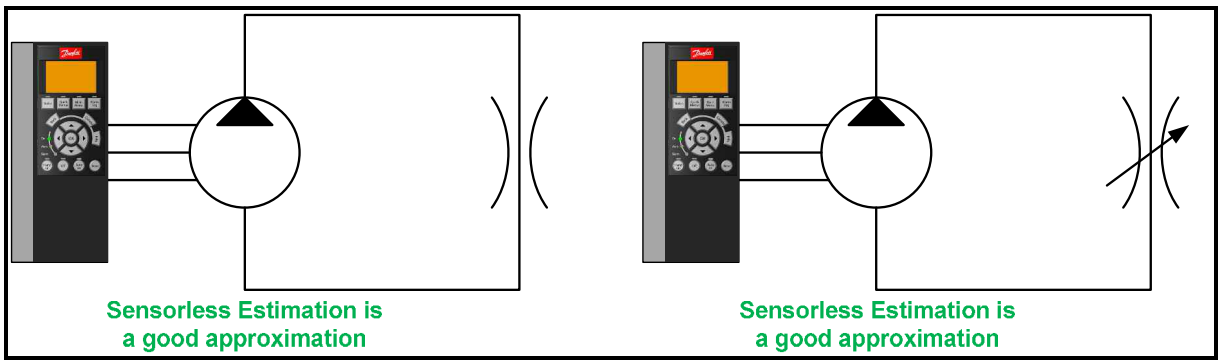


This concludes the setup of custom readout.

Sensorless Estimation Algorithm

The sensorless estimation method is based on the same algorithm as is utilized in the Danfoss Sensorless Pump Control. The method is based upon a number of between 5 and 100 measurements of pump curves (corresponding measurements of flow, head, frequency and power).

These data can either be provided by pump manufacturer (precision of data has to be verified) or be measured e.g. on a test setup with a variable valve. The major advantage is that the measurements can be performed once on any given pump and motor combination, and then this pump, motor combination can be utilized in any system. This includes systems with opening and closing of valves (cf. Figure below).



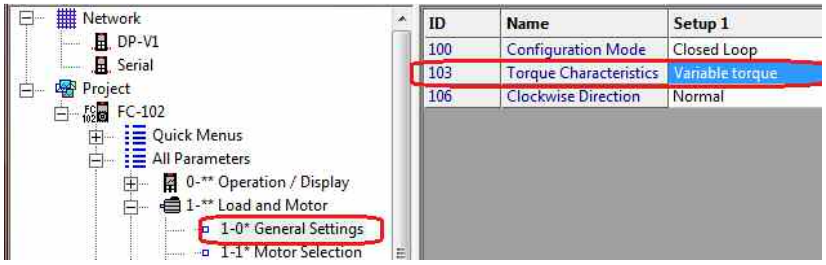
The pump data can be stored using MCT-10, and can be exported to other MCT-10 projects.

Step-by-step Guide for Sensorless Estimation

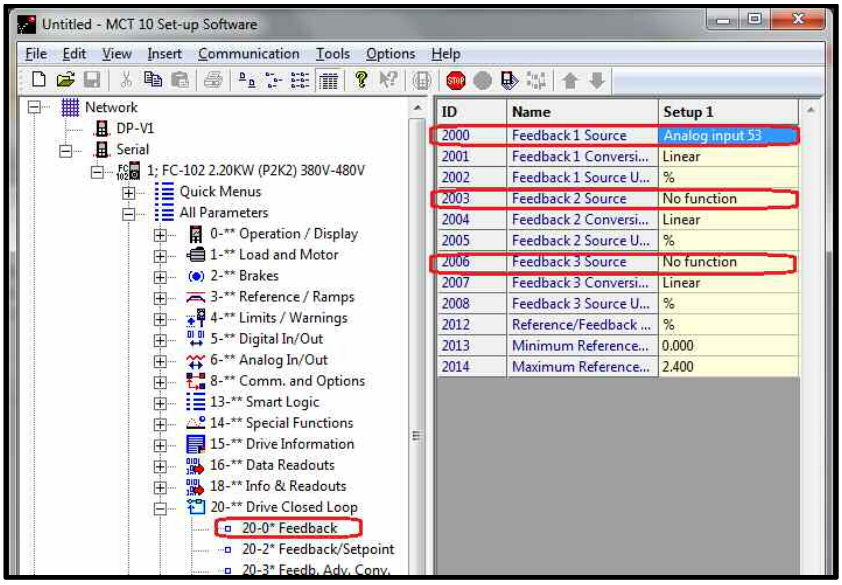
The following step-by-step-guide describes how to setup sensorless estimation of either pressure or flow:

First step is to make sure that the desired sensorless readout parameter is not set as the feedback signal of the closed loop control:

- Par. 1-00 'Configuration Mode': Check that the parameter is set as intended to either Open Loop or Closed Loop.
- Par. 1-03 'Torque Characteristics': Set parameter to 'Variable Torque'.

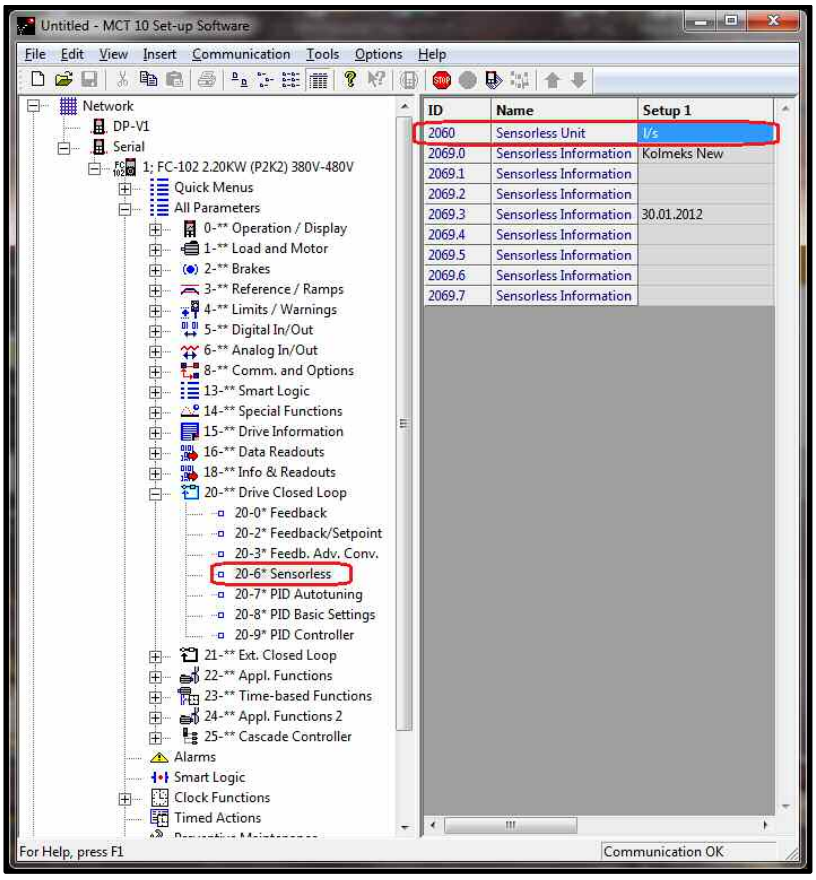


- Par. 20-00, 20-03, and 20-06 'Feedback X Source': Make sure that none of the three feedback Sources are set to the signal that has to be estimated (Sensorless Flow or Sensorless Pressure).



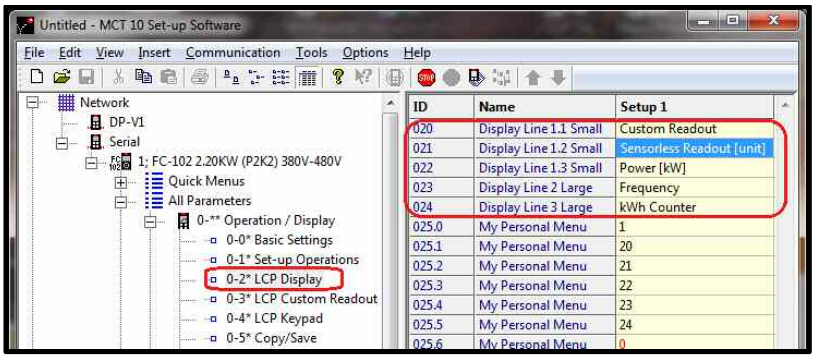
Second step is to select either pressure or flow readout:

- Par. 20-60 ‘Sensorless Unit’.

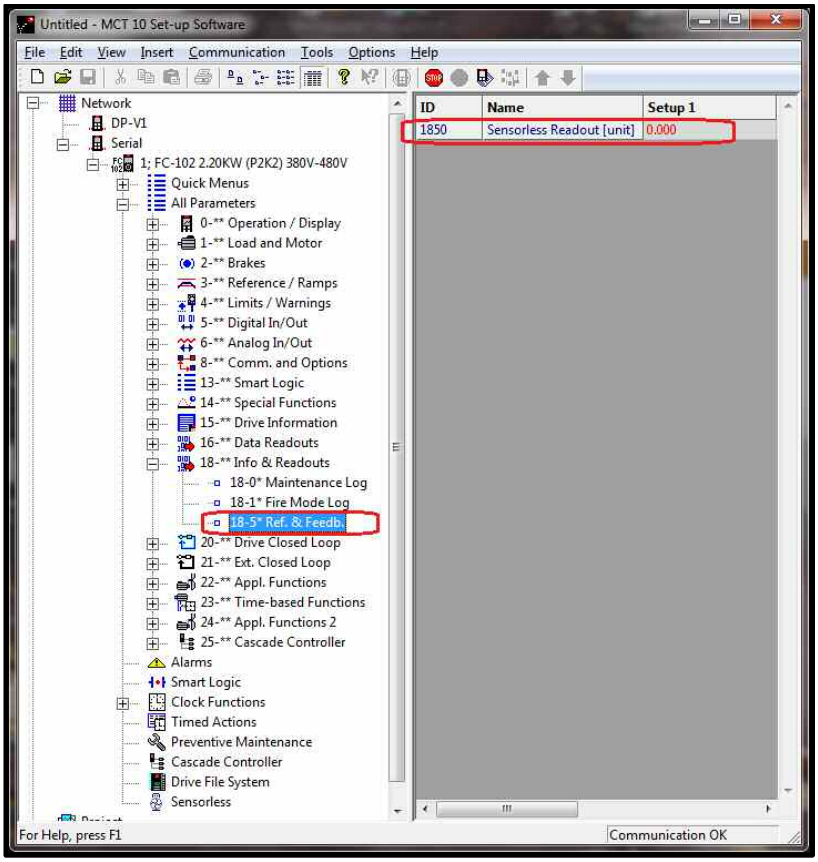


The next step is to read out the Sensorless Estimated signal in LCP or MCT-10.

- For read out in LCP set either of par. 0-20 through 0-24 to ‘Sensorless Readout [Unit]’.



- For readout in MCT-10 use par.18-50.



The final step is to import or create a database containing pump data, confer next sections.

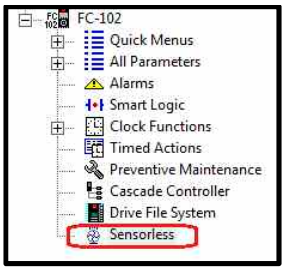
This concludes the guide to sensorless estimation readout.

The next subsections describe how to create or import a database containing pump data.

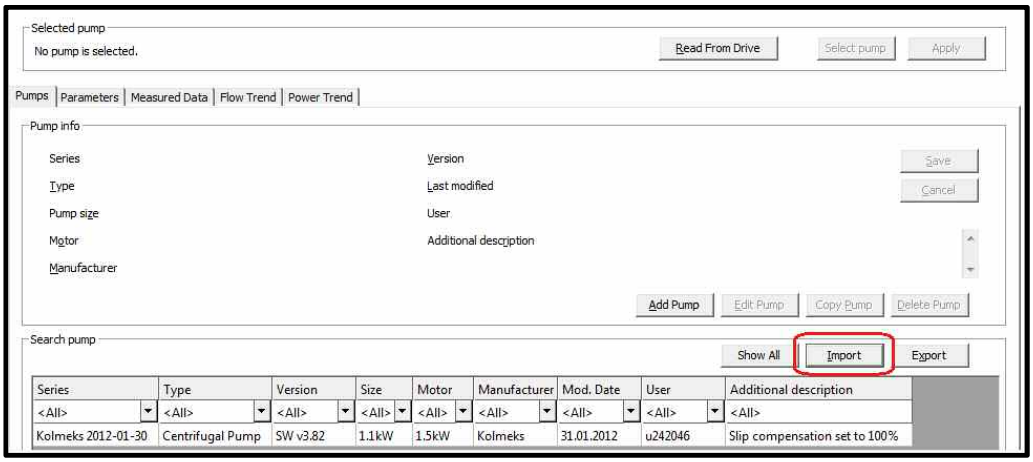
Step-by-step Guide to Importing Pump Data

The format of pump data for MCT10 is comma separated values *.csv and can be imported by following the procedure below:

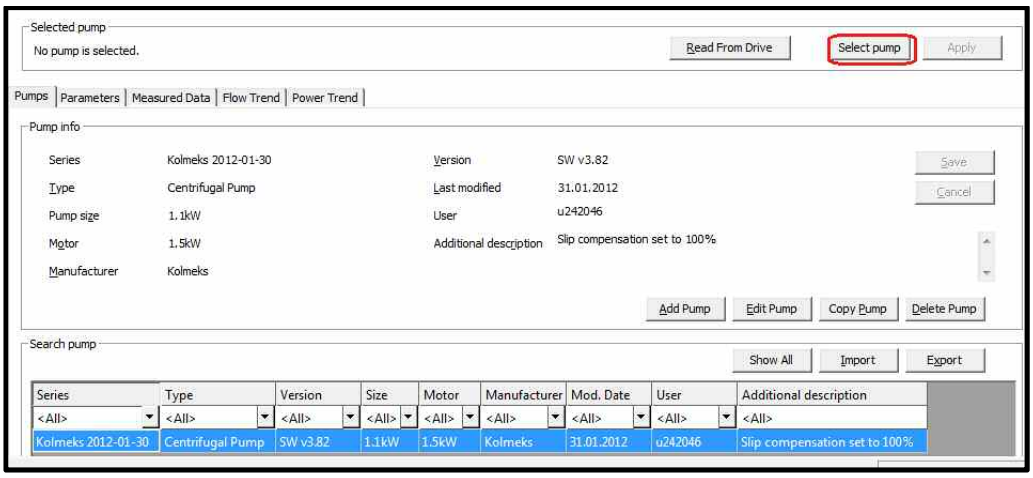
- Go to Sensorless folder in MCT10:



- Press Import:



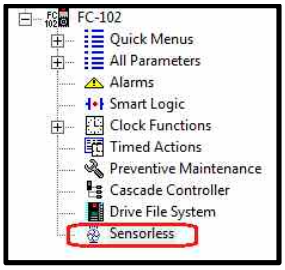
- Select pump data *.csv file and press open.
- Highlight pump, by right clicking, in 'Search pump' window and press 'Select Pump':



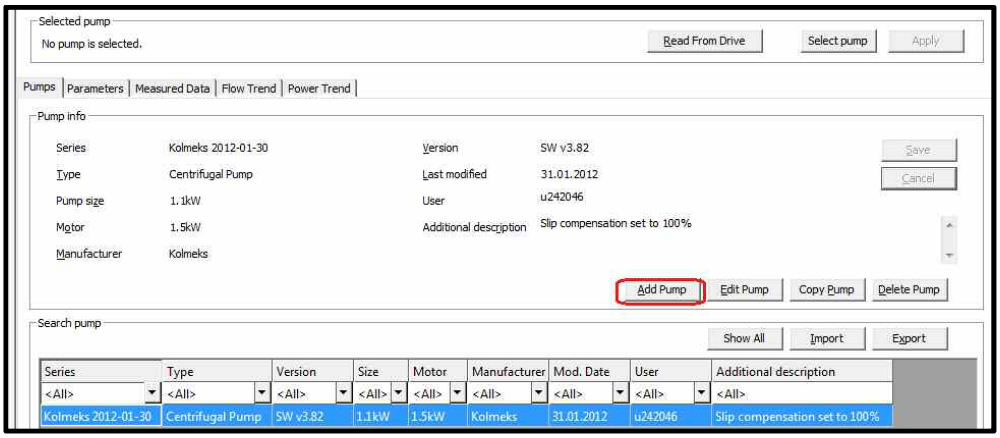
- Finally press 'Apply' to transfer pump data to the drive.
- This concludes the import pump data procedure.

Step-by-step Guide to Creating a Database of Pump Data

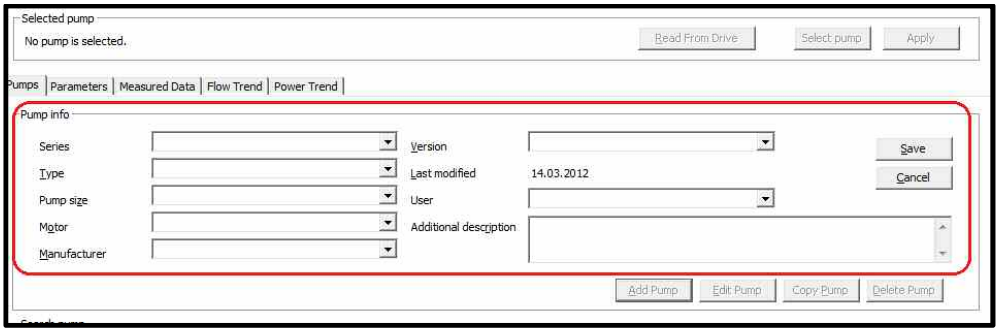
- Go to Sensorless folder in MCT10:



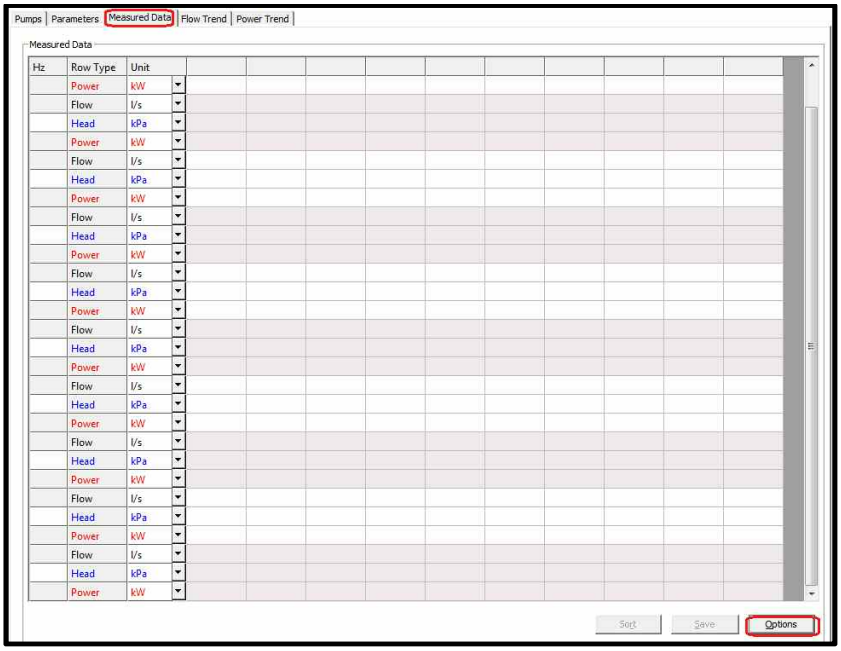
- Press 'Add Pump':



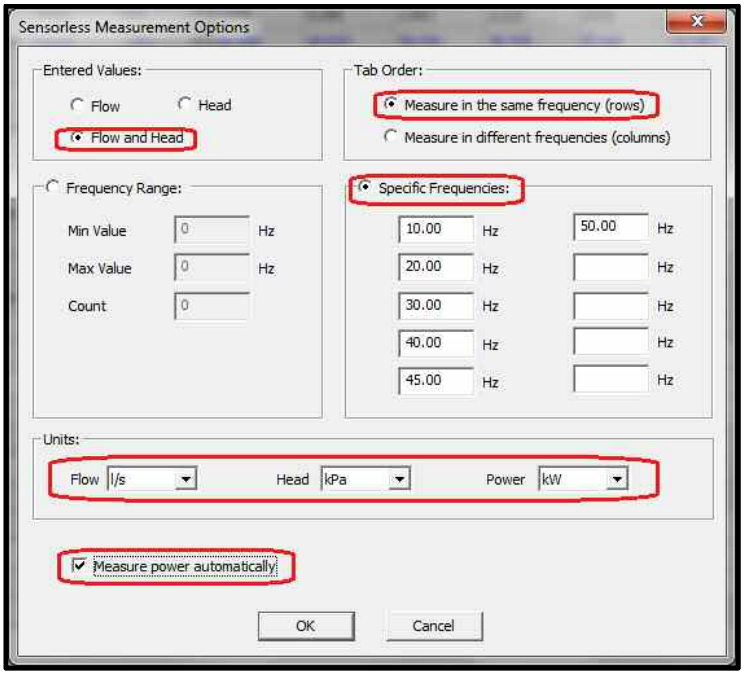
- Enter general information about the pump to be able to distinguish between different pumps and press 'Save':



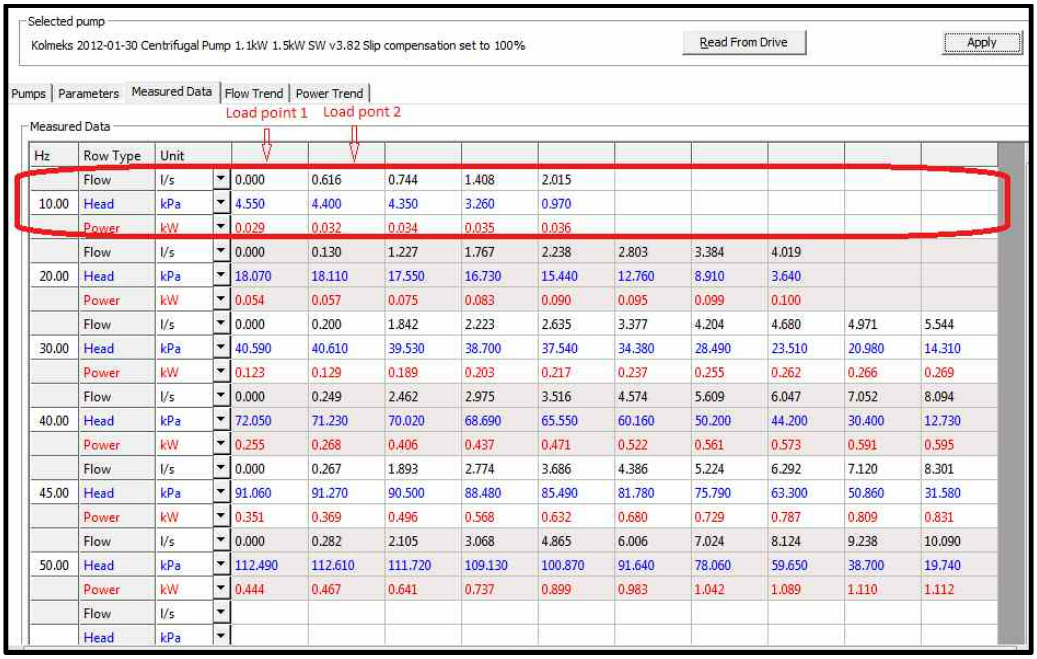
- 'Go to the Measured Data' tab and press 'Options':



- Select ‘Flow and Head’, and ‘Measure In the same frequency (rows)’, and specify the frequencies at which head and flow will be measured (should be spread equally on the full operating range – more points gives a higher estimation precision). Select units for flow, head and power according to measurement equipment (unit for power is not of importance). Check ‘Measure power automatically’ to make the drive read out power. Finally press ‘Ok’.

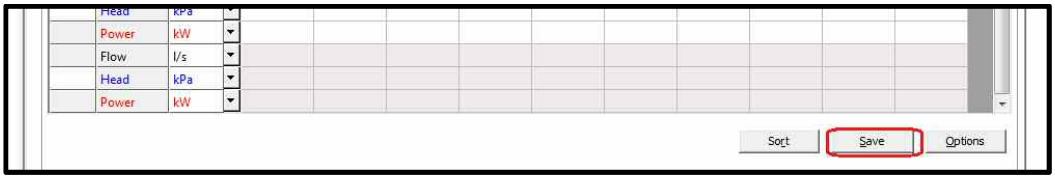


- Run at selected output frequency and measure flow and head at different load points (valve openings). More points equal higher estimation precision.

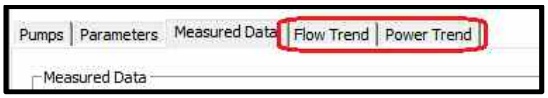


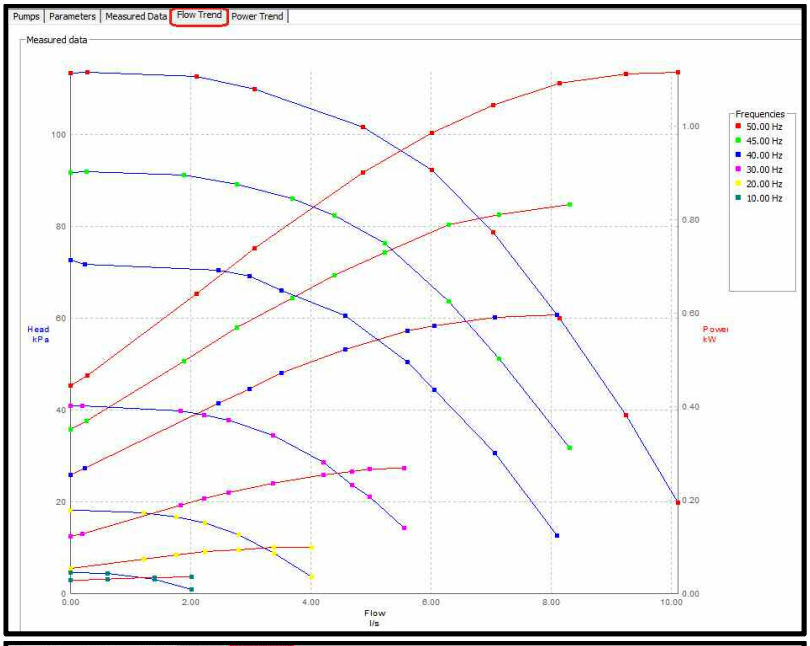
Hz	Row Type	Unit										
	Flow	l/s	0.000	0.616	0.744	1.408	2.015					
10.00	Head	kPa	4.550	4.400	4.350	3.260	0.970					
	Power	kW	0.029	0.032	0.034	0.035	0.036					
	Flow	l/s	0.000	0.130	1.227	1.767	2.238	2.803	3.384	4.019		
20.00	Head	kPa	18.070	18.110	17.550	16.730	15.440	12.760	8.910	3.640		
	Power	kW	0.054	0.057	0.075	0.083	0.090	0.095	0.099	0.100		
	Flow	l/s	0.000	0.200	1.842	2.223	2.635	3.377	4.204	4.680	4.971	5.544
30.00	Head	kPa	40.590	40.610	39.530	38.700	37.540	34.380	28.490	23.510	20.980	14.310
	Power	kW	0.123	0.129	0.189	0.203	0.217	0.237	0.255	0.262	0.266	0.269
	Flow	l/s	0.000	0.249	2.462	2.975	3.516	4.574	5.609	6.047	7.052	8.094
40.00	Head	kPa	72.050	71.230	70.020	68.690	65.550	60.160	50.200	44.200	30.400	12.730
	Power	kW	0.255	0.268	0.406	0.437	0.471	0.522	0.561	0.573	0.591	0.595
	Flow	l/s	0.000	0.267	1.893	2.774	3.686	4.386	5.224	6.292	7.120	8.301
45.00	Head	kPa	91.060	91.270	90.500	88.480	85.490	81.780	75.790	63.300	50.860	31.580
	Power	kW	0.351	0.369	0.496	0.568	0.632	0.680	0.729	0.787	0.809	0.831
	Flow	l/s	0.000	0.282	2.105	3.068	4.865	6.006	7.024	8.124	9.238	10.090
50.00	Head	kPa	112.490	112.610	111.720	109.130	100.870	91.640	78.060	59.650	38.700	19.740
	Power	kW	0.444	0.467	0.641	0.737	0.899	0.983	1.042	1.089	1.110	1.112
	Flow	l/s										
	Head	kPa										

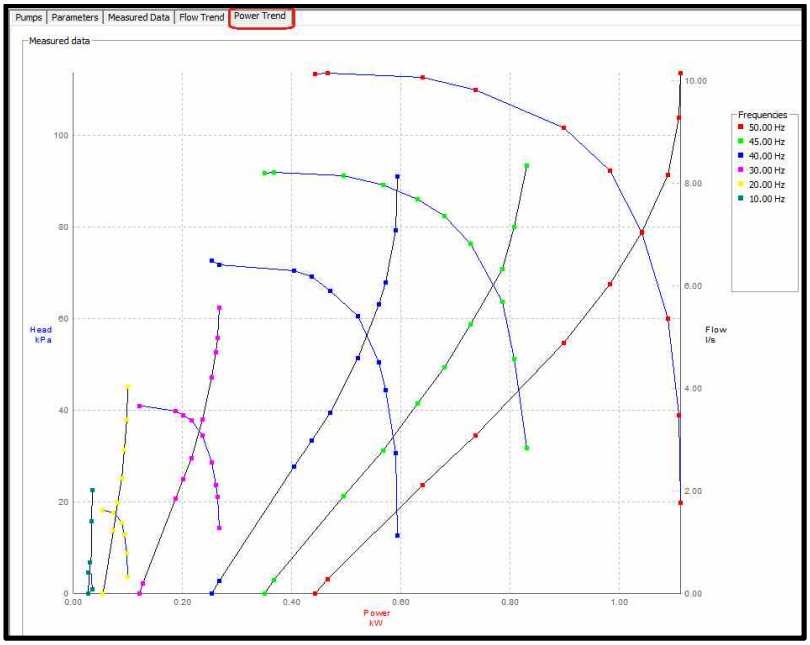
- Finish by pressing 'Save'. MCT10 will automatically require pump data to obey limitations as described in the next section. Data can only be saved once pump data obeys limitations (sort function might help to locate limitation violations).



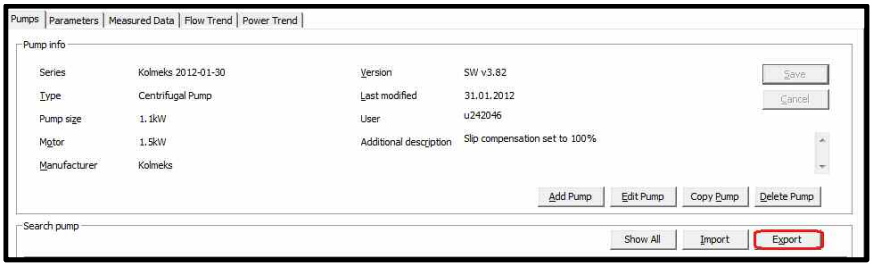
- Flow and Power Trends can be inspected in the corresponding tabs:



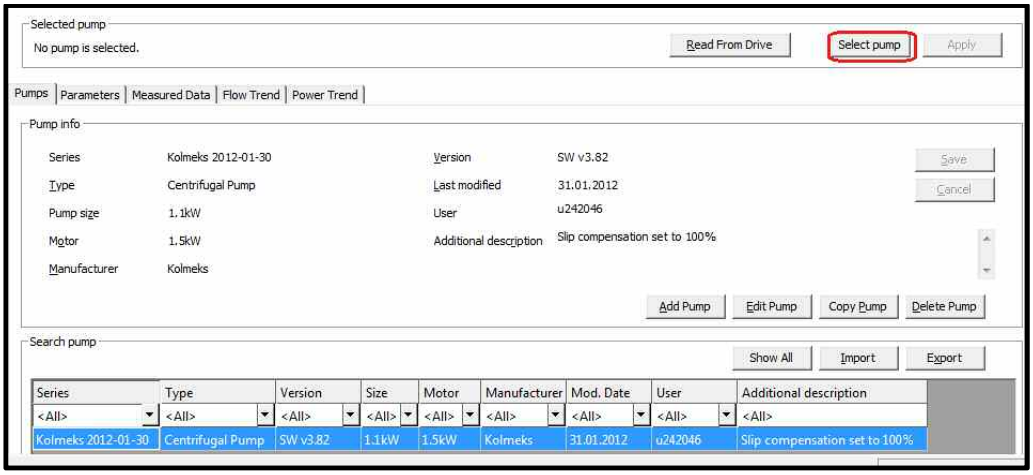




- Pump data can be exported to *.csv file by pressing 'Export' in the 'Pumps' tab:



- Highlight pump, by right clicking, in 'Search pump' window and press 'Select Pump':



- Finally press 'Apply' to transfer pump data to the drive.
- This concludes the creating pump database procedure.

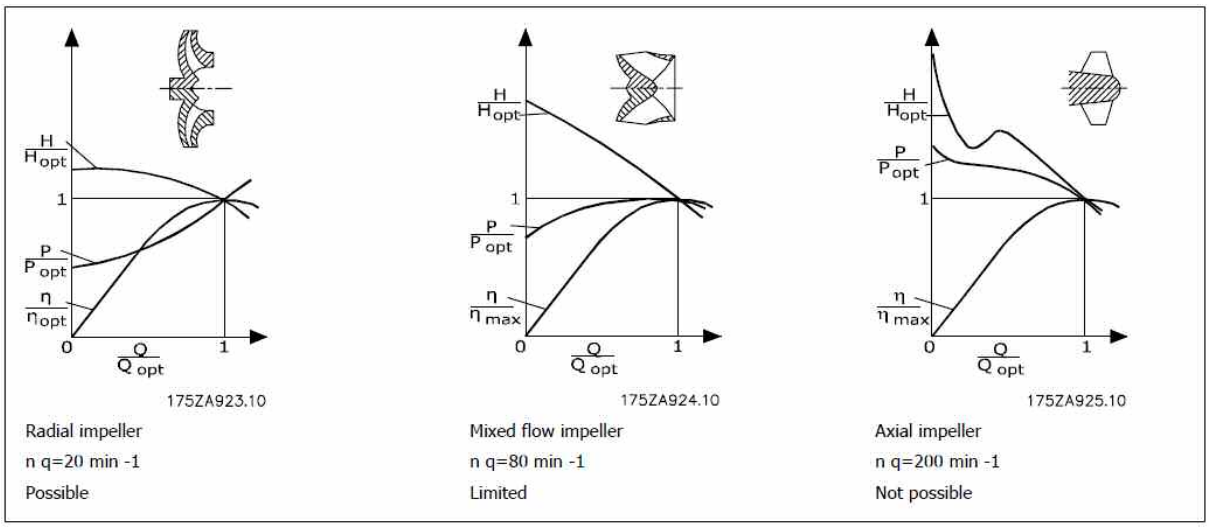
Pump Limitations for Sensorless Estimation

The Sensorless Estimation has the following limitations:

Sensorless estimation is for Induction motors only.

A criterion 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 cannot be used for sensorless estimation due to the particular shape of the head curve. The graphics below show typical characteristics for the different pump types.



Sensorless estimation 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 '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 sensorless function can only estimate pressure and flow in the range that data has been loaded into the drive.

Consequently 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 be smaller according to the affinity equations. The maximum flow at e.g. 25 Hz will therefore be 50 m3/h.