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Optidrive Applications Support Library

Application Note	**AN-ODV-3-068**
Title	**Using Optiflow Multi Pump Cascade Control**
Related Products	**Optidrive Eco**
Level **3**	1 – Fundamental - No previous experience necessary 2 – Basic – Some Basic drives knowledge recommended 3 – Advanced – Some Basic drives knowledge required 4 – Expert – Good experience in topic of subject matter recommended

Overview

Optidrive Eco features a unique Optiflow system, designed to simplify the operation of multiple pump sets, typically in Duty / Standby or Duty / Assist / Standby configurations. The system allows up to five drives, each controlling an individual pump to be connected together, and provides automation of the following functions.

- Automated changeover between Duty and Standby Pumps in the event of a pump fault
- Automated changeover based on time to allow balanced operating time between all pumps
- Automated Staging / Cascade Control of Duty and Assist Pumps in closed loop pressure or flow control applications
- Isolation of any individual pumps is possible whilst maintaining operation with the available pumps

Operating Principle

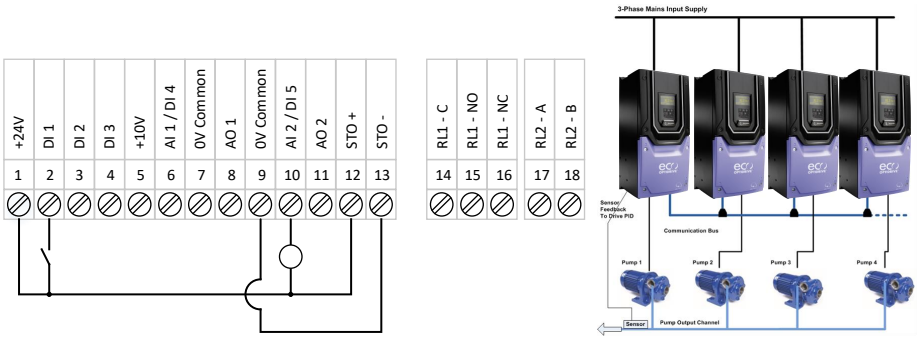
The Optiflow system operates on the principle that one drive is designated as the Control Master. All other drives operate as Slaves. The Master drive determines which pumps should operate at any given time, to ensure that only the required number of pumps are operating, and operating time is balanced between all pumps.

Control functions are carried out using the on-board RJ45 connector. The Control Master drive must be address 1. The connected Slaves must then have incremental addresses, starting from address 2.

All external control connections, such as feedback transducers, external setpoint and controls are made to the Master drive only. Slave drives simply require an enable input, to allow switching of individual slaves when required. Motor thermistors can also be connected back to each slave drive, and fieldbus connections for remote monitoring can also be made if required.

Installation

The installation of the drive should be carried out in accordance with the User Guide. The general control signals used for this application should be made as shown below:



When the system is operational, the enable/run command (DI1) must be given to all drives in the system – this will not make all the drives run immediately, it will simply permit them to run if they are required.

In addition to the above, the RJ45 serial communications port of each drive should be linked together, this can be done with standard RJ45 patch leads and cable splitters – see User Guide for further information.

Basic Commissioning

The basic commissioning instructions have been split into key steps to be carried out in the sequence in which they appear:

The master drive (address 1) is the one with the pressure transducer connected to it – it does not necessarily remain the lead pump during normal operation.

1. **Set the basic drive commissioning parameters as per the table below:**

Parameter	Description	Master	Slave 1	Slave 2	Slave 3
P1-01	Max Speed/rpm				
P1-02	Min Speed/rpm				
P1-03	Accel Ramp	2.0 (example)			
P1-04	Decel Ramp	4.0 (example)			
P1-07	Motor Rated Voltage	Motor rated Voltage – nameplate data			
P1-08	Motor Rated Current	Motor rated Current – nameplate data			
P1-09	Motor Rated Frequency	Motor rated Frequency – nameplate data			
P1-12	Operating Mode	3 (PID mode)	5 (Slave Mode)		
P1-14	Extended Menu Access	201			
P4-02	Autotune Enable	1			
P2-26	Enable Spin-Start	0			
P2-27	Standby Speed Timer	15 (example)			
P2-33	AI 2 Mode		N/A		
P5-01	Drive Address	1	2	3	4

Notes:

P1-03 & P1-04 For Accel and Decel Ramp values, it is usually best to use relatively short ramps. This should be tested on the pump set and if necessary, it can be modified later. The reason for using a short ramp is to get to the operational speed of the pump quickly to regulate the pressure when valves are opened and the flow increases.

P1-12 The master drive (drive with address 1) MUST operate in PID mode with P1-12 = 3 in order for Optiflow to work. The slave drives (drives with address > 1) must all be in slave mode.

P2-33 This is the mode for Analogue Input 2, and should be set according to the feedback transducer that is connected. If the transducer used is a 4-20mA signal then the correct setting for this parameter would be (4) t 4-20mA. With this setting, the drive would trip should the signal fall below 4mA.

P4-02 The autotune allows the drive to detect the motor characteristics for improved operation. For this, the motor needs to be connected and the STO circuit needs to be present. After the autotune, confirm the direction of rotation.

2. **To set-up the master drive** (after applying the settings in step 1)

Parameter	Description	Master	Comments
P3-01	PID P Gain	1.0 – 5.0	A value of 2.0 should be suitable but decrease if system is too reactive
P3-02	PID I Gain	0.5 – 2.0	A value of 1.0 should be suitable but increase if system is too reactive
P3-06	Pressure set-point	%	Set as percentage of full scale of the pressure transducer
P3-08	PID Output Low Limit	40 – 60%	Set this to the minimum speed in % of the pump to optimise the response of the PID wake-up process. e.g. 60% = 30Hz on a 50Hz motor
P3-13	PID Wake-up error	2.0%	This is the error between the PID Feedback and the reference in %
P3-14	PID Standby (sleep) speed threshold)		Sets the speed that the drive sits at (or below) for the duration set in P2-27 before the drive goes into sleep mode. See notes on following page
P8-14	Pump Staging	2	Sets the mode for multi-drive pump cascade
P8-15	Number of assist pumps		Set this as the value of assist pumps. For a 5 pump system, there is a master and four assist pumps so in this case enter a value of “4”
P8-16	Pump duty switch over time	1 (hours)	Used to limit the difference in operating hours for each pump – the changeover takes place when the difference in hours run of each pump reaches this value.
P8-17	Assist start speed		See notes below
P8-18	Assist stop speed		See notes below
P8-19	Pump Settling time	5 s	Sets the time for the system to stabilise after adding/removing a pump before it will add or remove another pump

P8-17 Assist Pump Start Speed

When Duty / Assist operation is required, this parameter controls the frequency at which an assist pump will be started. In general, a setting slightly below the maximum operating speed of the pump should be used, e.g. if P1-10 = 50.0Hz, P8-17 should be in the 45.0 – 49.9Hz range. In general, this approach will also provide the most efficient pump operation.

With a Duty / Standby pump set, P8-17 should be set to the maximum speed, e.g. P8-17 = P1-01. With this setting, the pumps operate in Duty / Standby mode only, without any Assist function.

Note : If P1-10 is set to match the motor nameplate Rpm, P8-17 will display in Rpm. If P1-10 = 0, P8-17 will display in Hz.

P8-18 Assist Pump Stop Speed

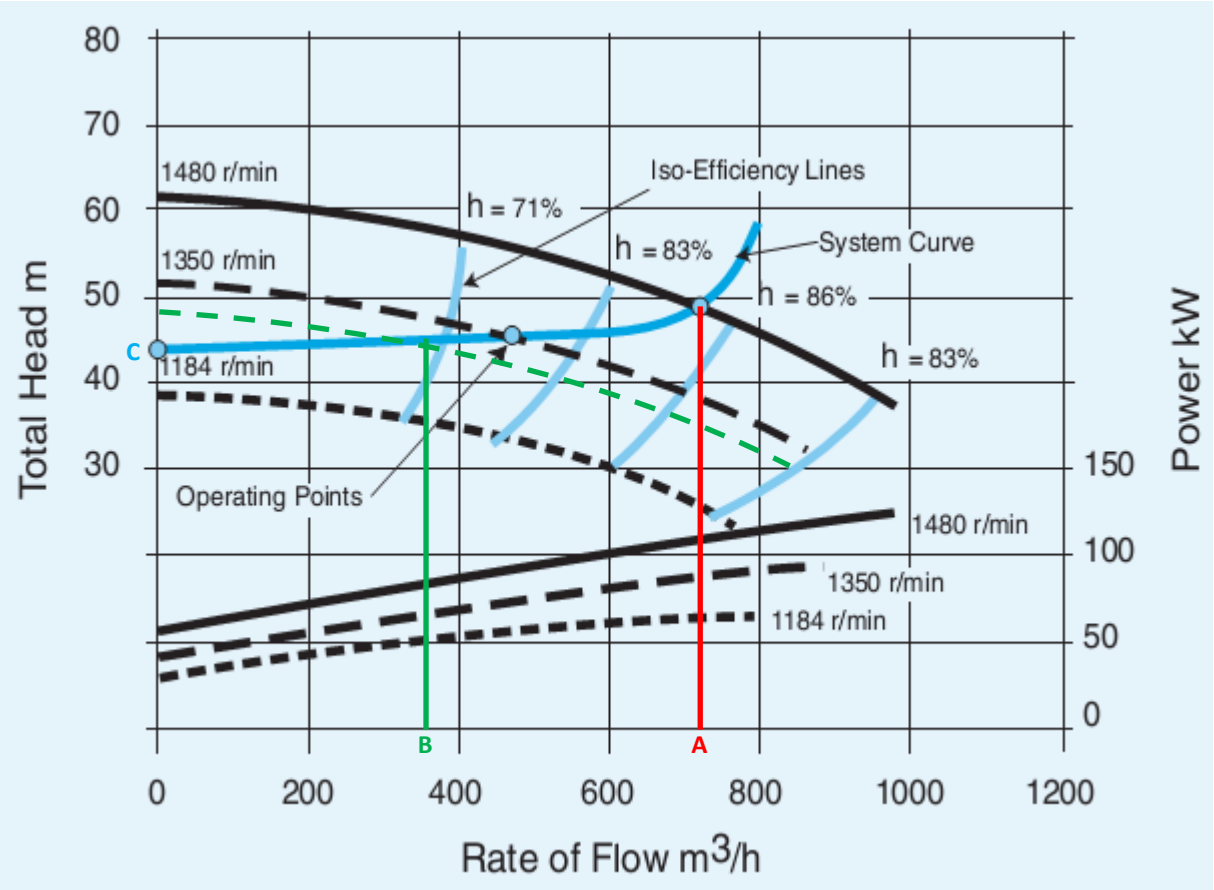
This parameter defines the operating speed of the pumps at which the assist pump/s are switched off. In general, systems that operate with higher pressure (head) will require a higher setting of this parameter.

In a simple Duty / Assist configuration, the required setting of this parameter can be determined, either by measuring or using the pump curve data to determine the flow produced by a single pump operating at maximum speed and required setpoint, then determining the speed at which two pumps operating in parallel will provide the same pressure and flow. P8-18 should then be set to this speed. See the example below for details on how this point can be estimated.

Where multiple assist pumps are present, e.g. 4 or 5 pump systems with multiple assist pumps, the same technique can be used to determine the optimum switch off point.

Assist Pump Start and Stop Speeds – Example Calculation

Below is an example of a pump flow curve, showing the available head and flow at various speeds, and the relative power consumed. A typical system curve is also shown, representing the required operating range of the pump up to maximum speed, along with the pump efficiency at various points.



From the curve above, we can see that a single pump operating at maximum speed and the chosen system point produces a flow level of around 720m^3/h. This is shown by the Red line A. As this point is closest to the optimum pump efficiency, the best system efficiency will be achieved by operating with only one pump up to the maximum flow of a single pump; hence in this case, the Assist Pump Start Speed parameter P8-17 should be close to maximum speed, e.g. 1475 Rpm / 49.9Hz.

Assuming we now have two identical pumps in parallel, to achieve the same flow demand and system operating point, each pump is required to produce 50% of the flow, 360m^3/h each. This is shown by the Green line B. From this point, we can estimate the pump speed required to produce this flow level, based on the shown Rpm curves. By following the green curve, this point can be estimated as approximately 1320 Rpm. The Assist Pump Stop Speed parameter, P8-18 should therefore be approximately 1320 Rpm / 44.0Hz in this case. These parameter settings can then be optimised during system test and commissioning.

To avoid rapid cycling of pumps, it is always advisable to set P8-18 slightly below the estimated value, to ensure that the final Assist Pump only stops when the flow demand drops below the level where a single pump can meet the demand, and repeated start / stop cycling of assist pumps is avoided.

P3-14 (& P2-27) Setting up the standby mode speed threshold and activation time

The standby mode speed threshold can be determined by calculation or by carrying out a test procedure. This paragraph explains how to determine the setting through carrying out a test. Disable the slave drives (can be done by removing the control terminal block) and run the master drive configured as above with the valves partially open to allow water to flow. The speed should now regulate to control the pressure. When the system stabilises, close down the valves to create a no-flow condition and record the speed that the drive settles at – this is the no-flow speed of the pump. A slightly higher (+2Hz) value than this should be entered into P3-14 on the master drive and all the slaves.

P2-27 sets the time at which the drive must be at or below the standby mode threshold before the drive enters the standby state – this is normally set to about 10 – 20s

With the standby mode configured **in ALL of the drives**, all the slaves should now be enabled and the system tested once again to ensure correct operation.

Example of Standby Mode Parameter Values Calculation

Referring to the pump curves shown earlier, it can be seen that following the Blue Line C, the minimum operating speed for the pump at which the system operating point can be met can be estimated. In this case, the value would be approximately 1250 Rpm. This value can be used for the Standby Mode Activation Speed, P3-14.

For consistent operation, of the system, P2-27 should be equal to or greater than the Pump Settling Time, P8-19. This ensures that Standby Mode is not activated during cascading of the Assist Pumps.

The PID Error Wake Up Level, P3-13 is entered as a % of the transducer range.

For example, in a closed loop pressure control system with a pressure transducer providing feedback, if a 0 – 10 bar feedback transducer is used, and the system is intended to operate at 4 bar working, it may be desired to switch the drive to Standby Mode, and only restart when the system pressure falls below 3.8 Bar. The PID Wake Up Error Level can then be calculated as

(4.0 – 3.8) / Transducer Range = 2.0%

Note : In order for Standby Mode to activate, the Output frequency must remain below the threshold set in P3-14 for the time set in P2-27. This requires the PID settings of the Master drive to be tuned correctly to ensure that the output frequency continues to drop when the system setpoint is held and no flow demand exists.

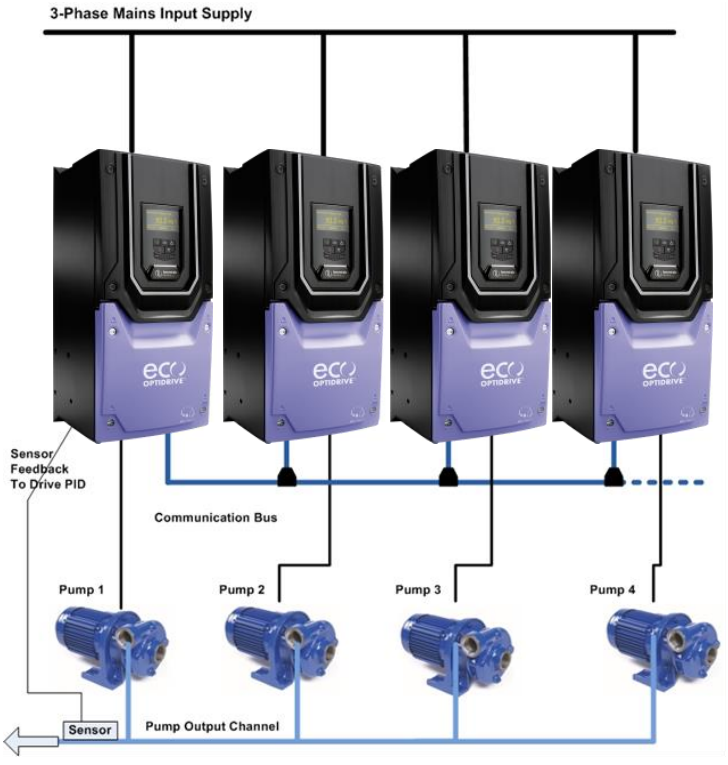
When Standby Mode is activated on the Master drive, the output of the PID controller will be set to zero. When the PID Error Wake up level exceeds the programmed threshold, the *PID Controller* will restart*. The drive will not recover from Standby until the output of the PID Controller exceeds the Standby Activation Speed*. For this reason, it is advisable to limit the minimum output of the PID Controller, based on the chosen Standby Mode Activation Speed.

PID Low Output Limit, P3-08 = (P3-14 / P1-01)% – 1.0%

E.g. In the example above, where maximum speed = 1500 Rpm, Standby Activation Speed = 1250 Rpm

P3-08 = (1250 / 1500)% - 1.0% = 82.3%

This setting ensures a rapid recovery from Standby Mode when required.



3. Final Optimisation

The pump set should now be working well but some further adjustments may be necessary for optimal performance. The table below describes various conditions and which parameters should be adjusted to improve performance:

Condition	General advice
Pumps do not go into standby mode and sit at a certain speed but without any flow (all valves closed)	The standby speed threshold **P3-14**, should be increased above the "no flow setting". Ensure that P8-18 is set at a higher value than **P3-14**.
When the valve is opened, the pressure drop of the system is greater than acceptable levels	Ensure that the acceleration ramp **P1-03** is as low as the system can comfortably tolerate. Decrease the PID I Gain **P3-02** in small steps and repeat tests. If this condition is present only when the slave drives are operational, review the value of the PID Wake-Up Level **P3-13**
Pumps overshoot the pressure set-point when started first time or when the system re-starts after going into standby mode	Increase the PID I Gain **P3-02** in small steps and repeat tests. Increase the acceleration ramp **P1-03** in small steps and repeat the tests.

4. Additional Notes

All drives in the system (master and slaves) will require the STO circuit to be energised and the run enable signal to be present on DI1 – see User Guide for further information.

The PID loop may need tuning using the PID gains in Menu 3.

It is advisable to set P3-08, the PID Controller Output Low Limit (%) to the same value that you set the minimum speed to as this will support a faster response to wake up from standby mode when the pumping demand increases. This setting is in percentage so if the motor rated speed (P1-10) is left at 0rpm (default) and the motor rated frequency is 50Hz, then set P3-08 = 2 x P1-02 (e.g. 2 x 20Hz(P1-02) = 40%).

Appendix:

Revision History			
Issue	Comments	Author	Date
01	Document Creation based on Optidrive HVAC	DD	14/09/15
02	Clarifications added based on customer feedback	DD	19/10/2017