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MICROMASTER 4

Application Description

PID filling level control with bumpless operating mode changeover

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PID filling level control with bumpless operating mode changeover

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2 Description

PID controllers are used to control a wide range of process quantities. A typical application is a closed-loop level control for a cooling water reservoir. With this application, the water level (PID setpoint) must be kept constant in the reservoir, independent of the amount of water flowing into the reservoir. This means that the speed of the pump must be adapted according to the quantity of the water that flows into the reservoir order to pump-out the appropriate quantity of water. The actual water level in the reservoir is detected using a filling level sensor (PID actual value). (Refer to Fig. 1)

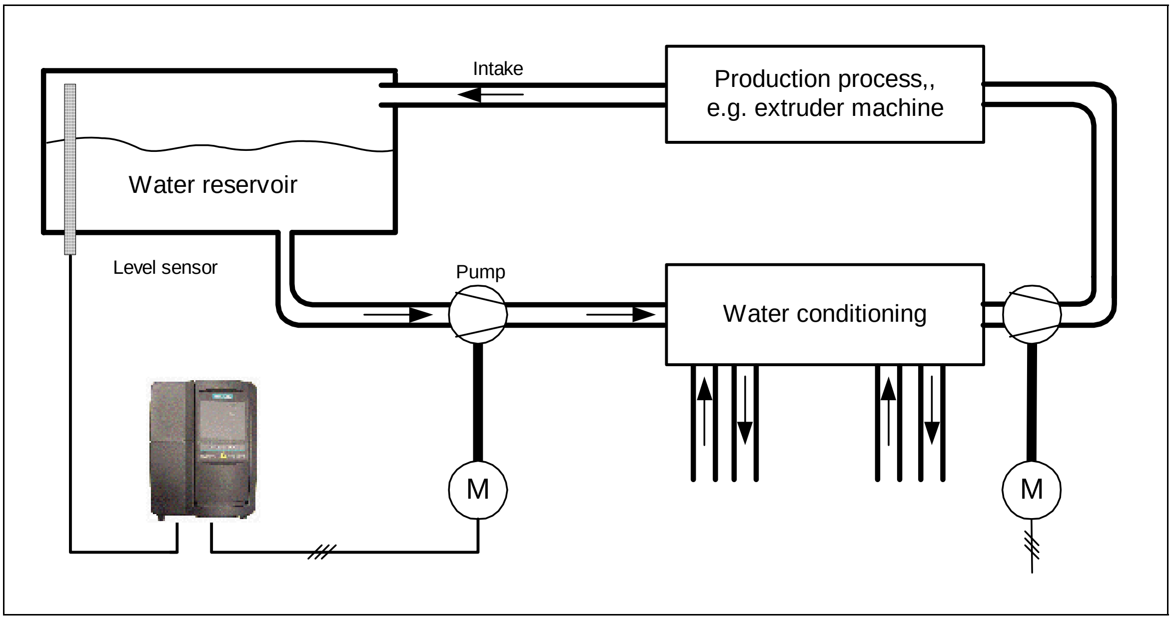

Fig. 1 Schematic diagram

Two pump operating modes should be provided - "automatic" and "manual". The mode is selected using a digital input, whereby the changeover between the operating modes is to be realized flying without shutting down the pump.

Automatic operating mode

In this mode, the AC drive inverter receives control commands and setpoints from a SIMATIC control e.g. via Profibus-DP. The AC drive inverter automatically controls (closed-loop) the water level using the internal PID controller. The level (PID actual value) is sensed by the level sensor that is connected to analog input 1 of the AC drive inverter. In addition, the sensed PID actual value is returned in PZD word 2 of the SIMATIC control and can be used for visualization on an HMI station.

Manual operating mode

In the "manual" mode the pump is locally controlled. This means that the control commands are set via digital inputs. The PID controller is no longer active and the pump is operated at a constant speed. The level is locally regulated by operating personnel by changing the speed using the internal motorized potentiometer function. This operating mode is predominantly used during cleaning and commissioning work, or when the level sensor fails.

Changing-over operating mode

The operating mode is changed-over between automatic and manual by selecting the appropriate command data set (CDS). The selection is made using digital input 2 (P0810=722.1). In this example, the 1st command data set is used for the "automatic" mode and the 2nd command data set, for the "manual" operating mode.

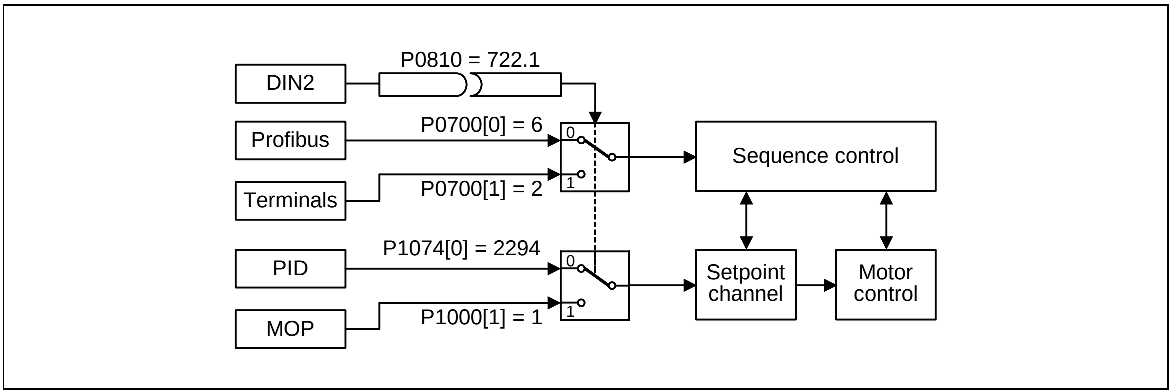

Fig. 2 Changing-over the command data set

PID controller

The PID controller, integrated in the drive unit is released or inhibited using parameter P2200. When enabled, the PID controller output is switched as setpoint after the ramp-function generator (no bumpless changeover). However, this behavior of the PID controller via P2200=1 is one thing. On the other hand, it is also necessary to be able to bumplessly select the operating modes on the fly. In order to fulfill this requirement, the modes, saved for the PID controller cannot be used. This means that parameter P2200 is set to 0!

Comment:

Independent of parameter P2200, the PID controller is always calculated using the frequency inverter software. This means that the PID controller output can be used as main or supplementary setpoint, independent of P2200.

In this particular application, corresponding to the actual command data set, a changeover is made between the PID controller output in the "automatic" mode and the motorized potentiometer in the "manual" mode as main setpoint (refer to Fig. 3).

Setpoint changes when changing-over the operating mode are implemented using the parameterized ramp-up and ramp-down time (P1120/P1121). This ensures that neither the drive inverter output frequency nor the motor frequency change suddenly (no step-function change).

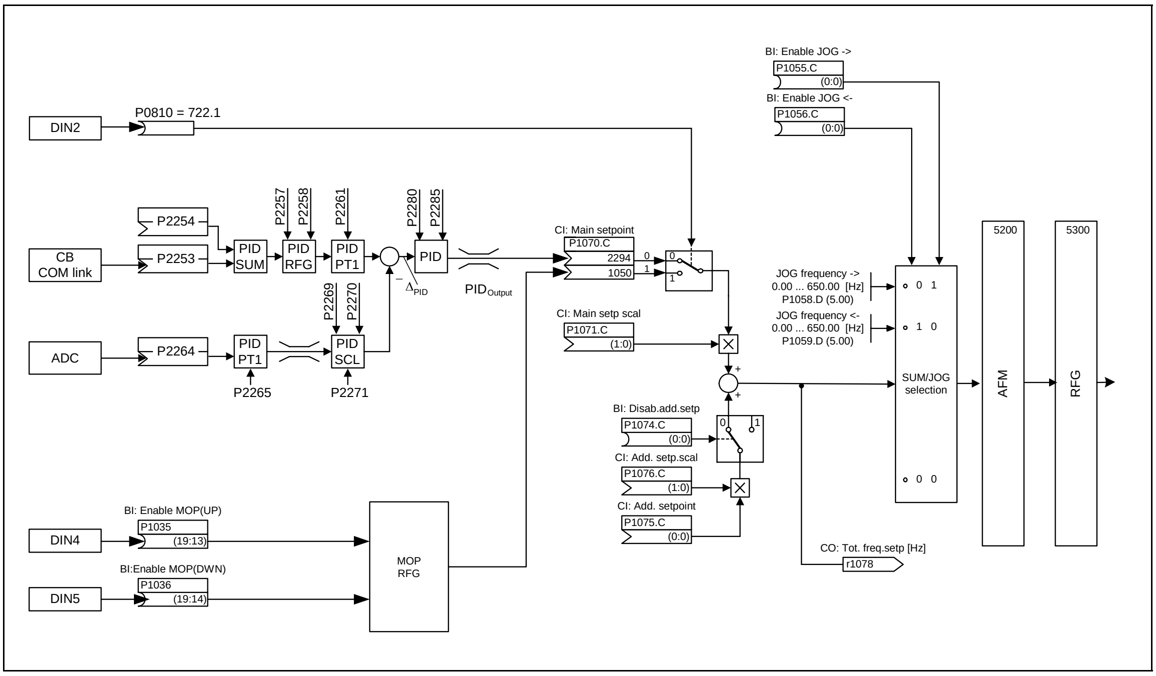

Fig. 3 Structure of the application example

In the "automatic" mode, from the perspective of the PID controller, the control loop is no longer so dynamic - but this shouldn't play a role in the closed-loop level control of the water reservoir.

PID filling level control with bumpless operating mode changeover

3 Important parameter settings

Parameter value	Designation	Note/ comments
P0700[0]= 6	P0700: Select command source 6: CB at the COM link	1. CDS; "automatic" mode
P0700[1]= 2	P0700: Select command source 2: Terminal strip	2. CDS; "manual" mode
P0702[0]= 99	P0702: Function, digital input 2 99: Enable BICO parameterization	1. CDS; "automatic" mode
P0702[1]= 99	P0702: Function, digital input 2 99: Enable BICO parameterization	2. CDS; "manual" mode
P0704[1]= 13	P0702: Function, digital input 4 13: Raise MOP (motorized potentiometer)	2. CDS; "manual" mode
P0705[1]= 14	P0702: Function, digital input 5 14: Lower MOP	2. CDS; "manual" mode
P0810= 722.1	P0810: CDS bit 0 722.1: Digital input 2	Selects the current command data set
P1000[0] = 0	P1000: Select the frequency setpoint source 0: No main setpoint	1. CDS; "automatic" mode
P1000[1]= 1	P1000: Select the frequency setpoint source 1: Motorized potentiometer setpoint (MOP)	2. CDS; "manual" mode
P1070[0]= 2294	P1000: Select main setpoint 2294: PID controller output	1. CDS; "automatic" mode“
P2051[1]= 755.0	P2051[1]: PZD at CB, 2nd word 755.0: Analog input 1	PID actual value is transferred to the control
P2200= 0	P2200: Enable PID controller 0: PID controller inhibited, i.e. no PID mode active	Refer to FP5000
P2251= 0	P2251: PID mode 0: PID controller as main setpoint	PID mode
P2253[0]= 2050.1	P2253: PID setpoint 2050.1: 2nd received PZD word of the communications module (CB)	1. CDS; "automatic" mode
P2253[1]= 0	P2253: PID setpoint 0: 0%	2. CDS; "manual" mode
P2257= 0	P2257: Ramp-up time of the PID setpoint 0: 0s: Recommended setting	This value can be adapted while commissioning the application.
P2258= 0	P2258: Ramp-down time of the PID actual value 0: 0s: Recommended setting	This value can be adapted while commissioning the application.
P2264[0]= 755.0	P2264: PID actual value 755.0: Analog input 1	1. CDS; "automatic" mode
P2264[1]= 0	P2264: PID actual value 0: 0%	2. CDS; "manual" mode
P2293= 0	P2293: Ramp-up/ramp-down time of the PID limit value 0: 0s: Recommended setting	This value can be adapted while commissioning the application.

PID filling level control with bumpless operating mode changeover

4 Terminal strip assignment

Terminal	Designation	Function in the operating mode	
		"automatic"	"manual"
3 -4	Analog input 1	-	PID actual value
5	Digital input1	-	On / OFF 1
6	Digital input 2	Select "automatic/manual" mode	
7	Digital input 3	Error acknowledgement	Error acknowledgement
8	Digital input 4	-	Raise MOP
9	Digital input 5	-	Lower MOP

5 Additional information

This application example only indicates the principle strategy. The definitions for the individual modes can be selected quite differently. It would be conceivable, for example, that only the PID controller is disabled in the "manual" mode - but control commands and setpoints are still transferred from the control.

During commissioning, initially, the ramp-up/ramp-down times P1120/P1121 should be set as low as possible, i.e. without the frequency inverter going into a fault condition with overcurrent (F0001) or overvoltage (F0002). From the perspective of the PID control, the ramp-up/ramp-down times act like a deadtime in the control loop. This means that the control performance that can be achieved for the application depend significantly on the selected times.

The PID controller (P2200=0) is not enabled. This means that automatic controller optimization (P2350> 0) is not possible. The PID controller setting values should be manually determined during commissioning. In this case it is extremely helpful to display the PID controller output, the PID actual value or the drive inverter output frequency as trend characteristic on an HMI station or trace this using an oscilloscope. In order to set the PID controller, initially, the ramp-up and ramp-down time of the PID setpoint (P2257/2258) should be set to 0 s. The optimum setting of the PID proportional gain (P2280) and the PID integral time (P2285) can be determined by using ± 5-10% steps of the PID setpoint. The ramp-up/ramp-down time of the PID limit value (P2293) has no effect as, when the PID controller is inactive (P2200=0), the selected PID limit values are immediately active.

The trace displays (refer to Fig. 4) of the flying operating mode changeover with the following settings at the frequency inverter:

P1120	ramp-up time	5.00s
P1121	ramp-down time	5.00s
P2257	ramp-up time for the PID setpoint	0.00s
P2258	ramp-down time for the PID setpoint	0.00s
P2280	PID proportional gain	3.000
P2285	PID integral time	1.000s
P2293	ramp-up/ramp-down time of the PID limit value.	0.00

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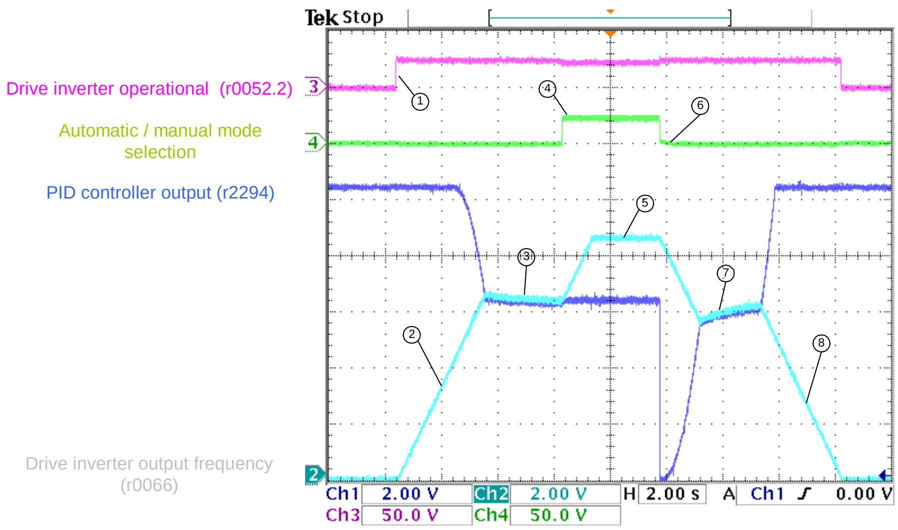

Fig. 1 Example of a trace showing how the operating mode is changed-over

1. The frequency inverter is powered-up in the automatic mode;
2. The output frequency is ramped-up corresponding to the PID controller output.
3. The PID controller automatically adjusts itself to the PID setpoint
4. The mode is changed-over to "manual"
5. The output frequency is increased to the actual motorized potentiometer setpoint via the ramp-function generator
6. The mode is changed-over to "automatic"
7. The PID controller again automatically adjusts itself to the PID setpoint
8. The drive inverter is powered-down; the output frequency is ramped-down