APPLICATION EXAMPLE

Configuration of Override Control

SIMATIC PCS 7 V9.1 SP2

SIEMENS

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1. Preface

1.1. Objective of the Application

In an override control scheme, two or more controllers must share one actuator. Depending on the actual process conditions a switchover logic decides which controller accesses the actuator i.e., the various controllers can "override" or replace each other.

The present project example shows an application of an override control to a simulated process with two controllers. The aim of this application is demonstrating different switchover strategies with the respective advantages and disadvantages.

1.2. Main Contents of this Application Note

The following issues are discussed in this application note:

- Interaction of the two controllers on only one actuator, considering two different alternatives for the switchover logic and two different types of PID controllers.
- Simulation example

1.3. Components used

This application example has been created with the following hard- and software components:

Component	Number	Article Number	Note
PCS 7 V9.1 SP2	1	6ES7658-...68-....	

Table 1-1

You can purchase these components from the [Siemens Industry Mall](#).

2.   Introduction

2.1.   Basic Principles of Override Control

In an override control scheme, two or more controllers share a common actuator. Depending on the current process state, a decision is made as to which controller actually has access to the actuator, in other words, the various controllers can override each other.

A typical use case is a gas pipeline with pressure and flow control using a single valve. The main control target is to achieve a certain flow rate, however due to safety considerations, the pressure must be kept within certain limits. The pressure controller is therefore known as the "limiting controller" or "secondary controller". (Remark: "Safety" in this context and in the whole article means the adherence of limits, it is not intended to replace special safety aligned controls, emergency stops etc.).
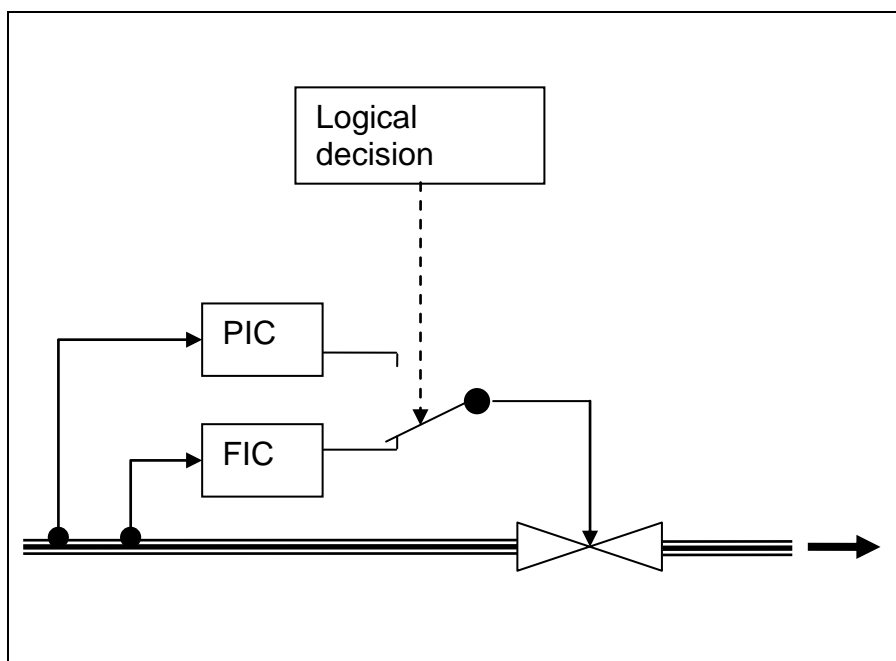

Figure 2-1 Override control with main controller for flow (FIC) and limiting controller for pressure (PIC)

Controls with more than two controlled variables are possible but rarely found. An example is the supervision of the temperatures in a bigger boiler or reactor with an inhomogeneous temperature distribution. The temperature is measured in a variety of locations but there is only one control action: the overall heating power. If a "hot spot" occurs at any measuring point and the temperature overruns the specified limit, this temperature becomes the leading controlled variable to throttle the heating.

2.2. Criteria for Different Kinds of Override Control Schemes

The logical decision as to which controller should be active can be made based on two different criteria resulting in two different types of override control schemes:

Limiting Control

The decision is based on a measurable process output variable, for example one of the two controlled variables. In the example above, the warning limits of the pressure controller can be used to decide whether the pressure controller should be active. The passive controller is in tracking mode to avoid windup problems and to ensure bumpless transfer. The setpoint of the secondary controller must be somewhat lower than the switchover threshold so that the transfer can be reversed again. This type of override control is easy to understand and to implement. Its advantage is that the high and low limit of the secondary controlled variable (for example pressure) can be monitored; its disadvantage is that a limit cycle oscillation results as soon as the limiting controller needs to intervene. The secondary controller will always attempt to return its controlled variable to the safe range and to return command to the main controller (for example flow rate) so that the active and passive controllers swap over continuously. This variant is therefore only recommended when the secondary controller is rarely required and works mainly as a safety or backup system.

Selection of Manipulated Variable

The decision is based on a comparison of the manipulated variables of both controllers, for example the controller that demands the higher (or lower) manipulated variable takes control of the actuator. In the example above, the controller that wants to open the valve further takes control. The setpoint of the secondary controller defines the switching threshold. Both controllers run the entire time in automatic mode. To avoid windup problems, the manipulated variable limits must be tracked in a crossover structure: When the higher (lower) manipulated variable wins, the low (high) limits of all controllers of the currently highest (lowest) manipulated variable must be corrected slightly up or down by, for example, 2% of the manipulated variable range. This means that this scheme can also be used in applications with more than two controlled variables. There is no windup problem at the high limit because the highest manipulated variable takes control anyway. This approach avoids the limit cycle oscillation of alternative 1 but is in principle asymmetrical, in other words either a high or a low limit of the secondary controlled variable can be monitored but not both.

2.3.   Application Examples

Steam generator

The primary controlled variable is the steam pressure but the water level in the steam tank must be monitored so that the heating coils remain completely covered by water and the tank does not overflow. The only manipulated variable is the outlet valve position.
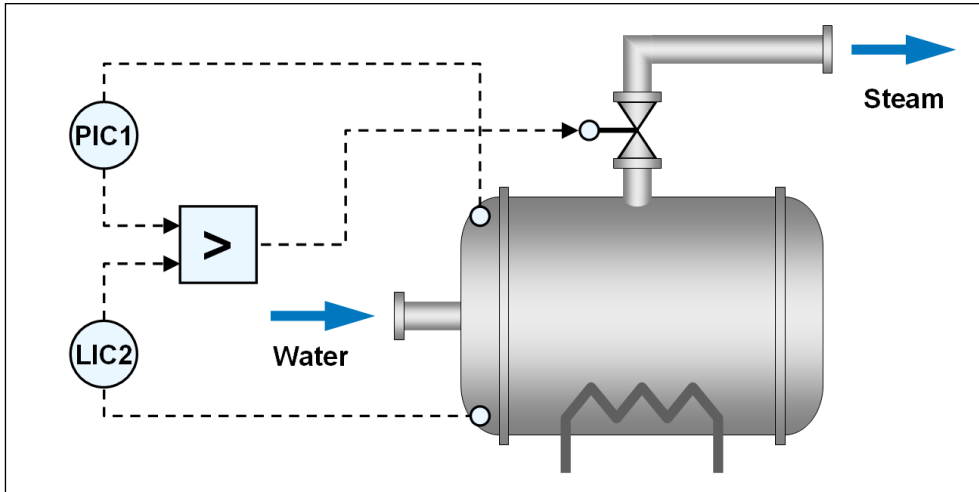

Figure 2-2 Override control of a steam generator

Compressor

The primary controlled variable is the delivered throughput, but the pressure must be monitored to make sure it does not exceed a safety limit. The only manipulated variable is motor speed.
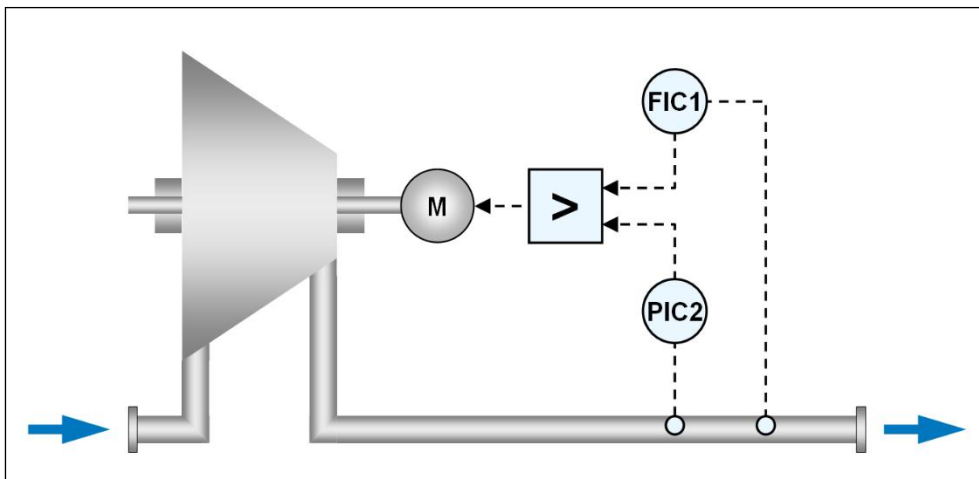

Figure 2-3 Override control of a compressor

Steam distribution system

Every process plant has a network of pipes to distribute hot steam at various pressures throughout the plant. The pressure of high-pressure steam is reduced to lower levels via a valve. The primary controlled variable is the pressure at the lower-level stage, however the pressure in the high-pressure piping must also be monitored to make sure that it does not exceed a safety limit.
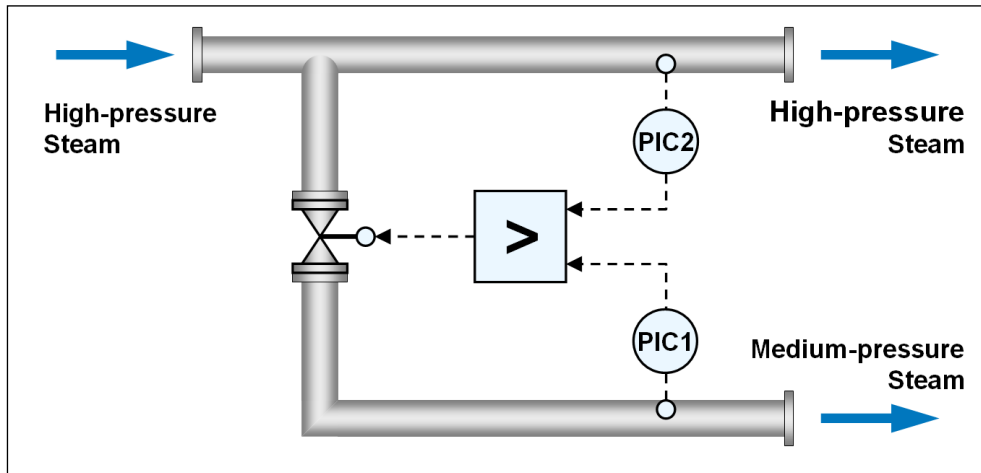

Figure 2-4 Override control for steam distribution system

3. Configuration of Override Control

If you implement a new cascade control structure in your project, it is recommended to make use of the process tag type "OverrideControl" from the Advanced Process Library.

3.1. Creating an Instance of the Process Tag Type

The following steps are carried out for the override control in the same way as for any other process tag type.

1. Open the Advanced Process Library with SIMATIC Manager: Open project > Library > PCS 7 AP Library V91.
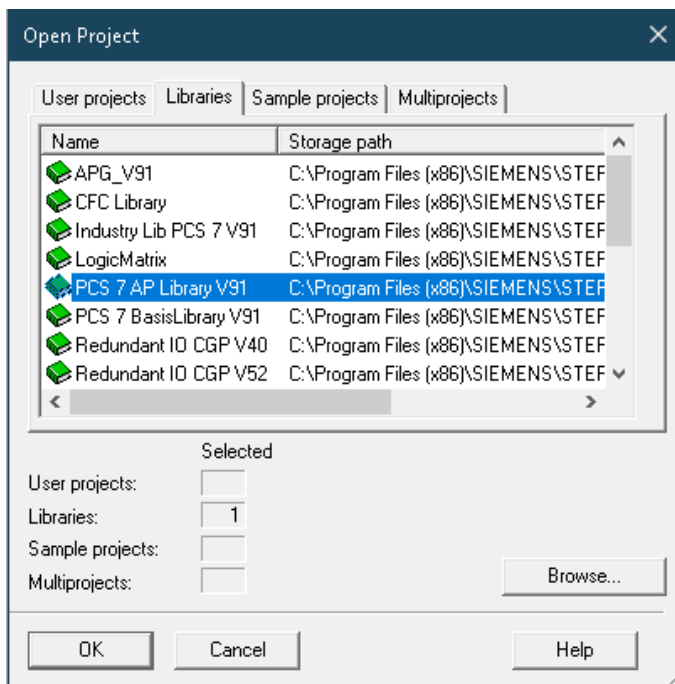

Figure 3-1 Open the "PCS 7 AP Library V91"

2. Copy the process tag type "OverrideControl" from the Plant View, folder "Templates > Control" into the master data library of your PCS 7 Multiproject and modify it if necessary, according to your general application requirements.
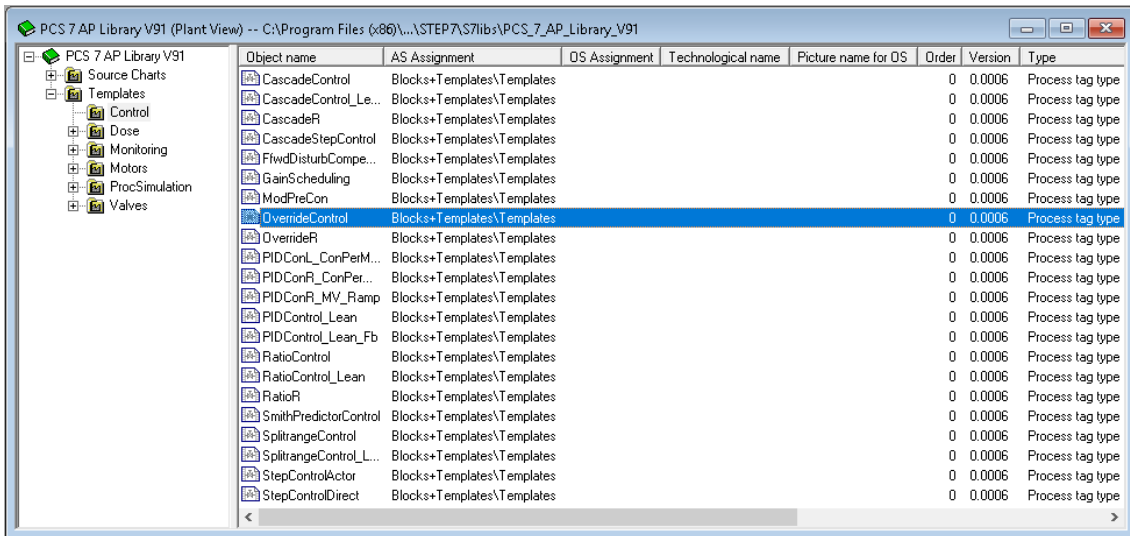

Figure 3-2 Selection of process tag type

3. Copy the process tag type from the master data library to the application part <project name>_Prj of your Multiproject, in the appropriate target folder (Process cell/Unit etc.) in the plant view. You obtain an instance of the process tag type i.e., a CFC chart, which indicates its origin by its symbolic representation.

4. Rename the new CFC chart and check if the cyclic interrupt OB is correct (in the CFC chart "Edit > Open run sequence").

Because of both PID algorithms of the primary and secondary controller work independently from each other, it is not stringently necessary that the two controllers run in the same time cycle. It is nevertheless the simplest solution to put the two controllers and the switch over logic (i.e., the complete process tag type) in one cyclic task, using a cycle time which is reasonable for the faster of both single control loops.

3.2.   Manual Configuration

If you manually configure the override control i.e., you don't use the predefined process tag type, please take care of the issues with respect to connection for both variants (according with chapter 2.2) in the next two sections.
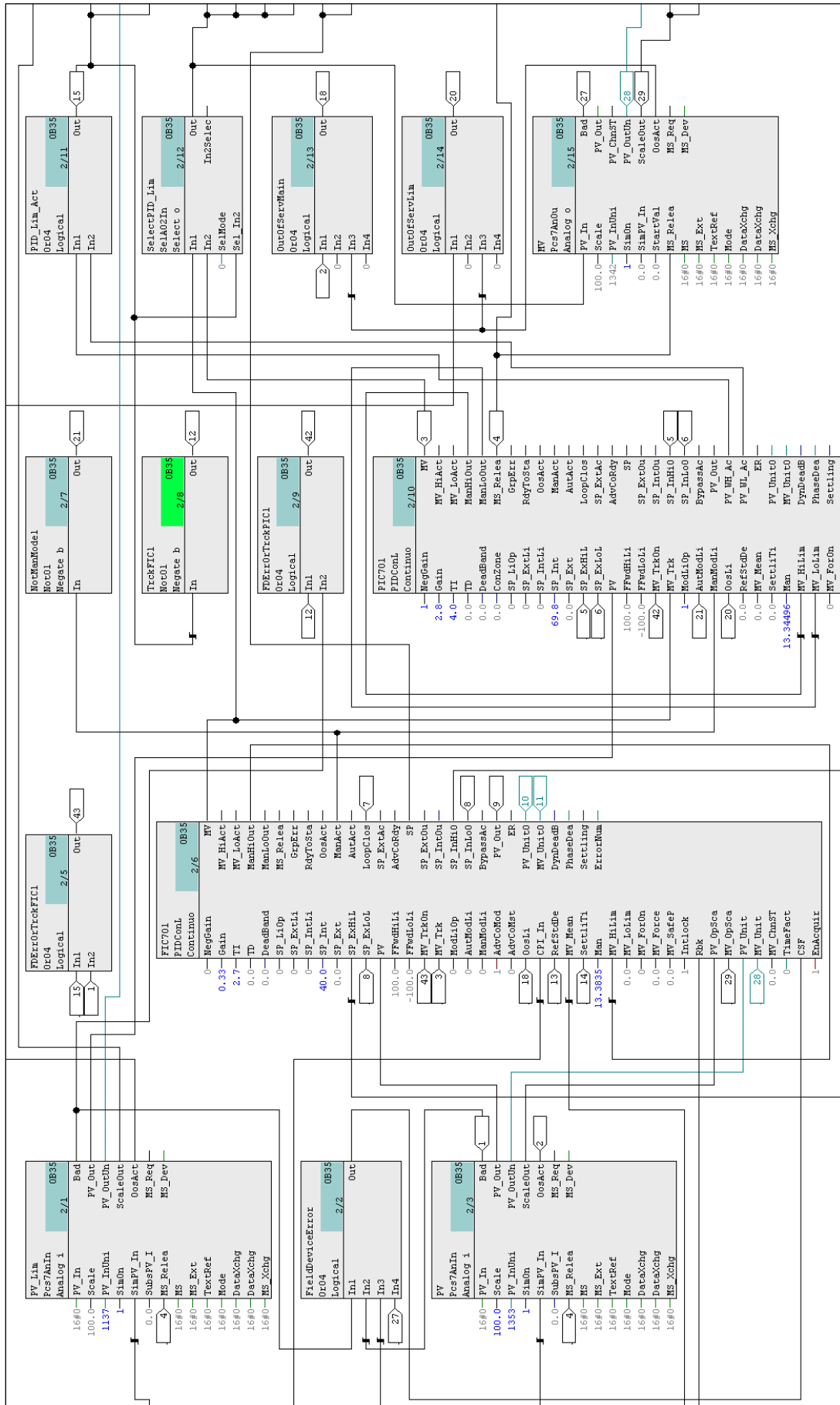
3.2.1. Limiting Control

Figure 3-3 Override control with limiting controller

The OR block PID_Lim_Act checks if the limiting controller reaches the upper or lower warning limit of the controlled variable. The output parameter of the PID_Lim_Act block is connected to the SelectPID_Lim block. This block switches the manipulated variable of the limiting controller to the MV Output block if a warning limit is reached. As long as the controlled variable of the limiting controller is within the warning limits, the limiting controller is tracked by the FDErrOrTrckPIC1 block. If the limiting controller is outside the warning limits, the main controller is tracked by the FDErrOrTrckFIC1 block. The tracking value comes from the manipulated variable output of the respective active controller. If any controlled variable of the controllers is disturbed or missing (bad signal status), the controllers are also forced into tracking mode, and additionally the input parameter CSF of the main controller is set.

Only one controller is active at a time, the other controller is tracked. The tracking mode is displayed by the standard block symbol on the operator station.

A control performance monitoring with the ConPerMon block is only provided for the main controller and is deactivated if the main controller is tracking. Due to the different properties of the flow and the pressure-controlled system the variances are naturally different even in a well-tuned state of the control loops. Therefore, it makes no sense to require the control performance (variance) of the primary controller equally from the secondary controller.
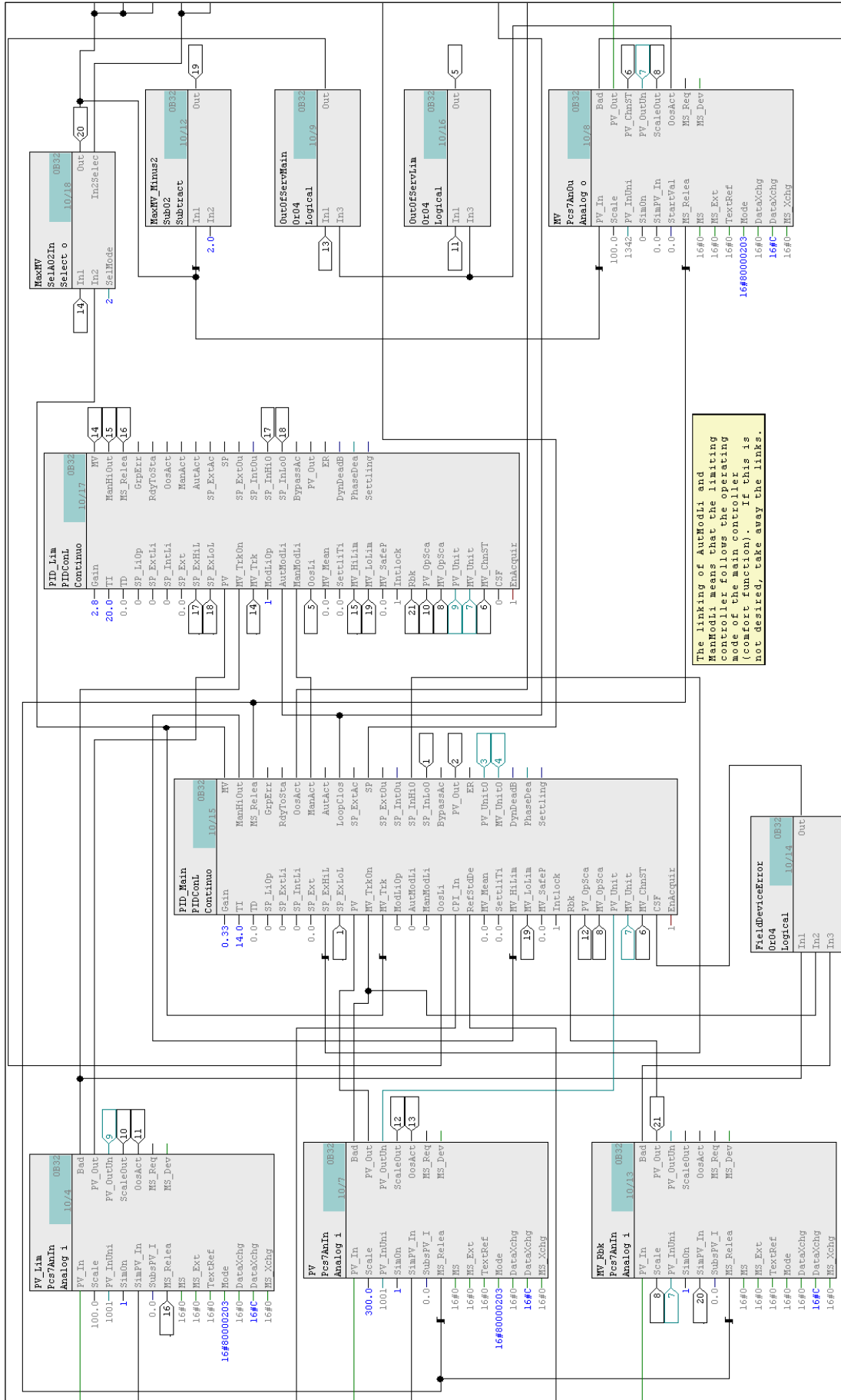
3.2.2.   Selection of the Manipulated Variable

Figure 3-4 Override control with selection of the manipulated variable

With a SelA02In block the maximum (minimum) of both manipulated variables of main and limiting controller is selected and connected to the single actuator.

With a subtractor (adder) a low (high) limit for the manipulated variables is calculated marginally below (above) of the active manipulated variable (in the example MaxMV_Minus2).

If the major (minor) manipulated variable wins, the lower (upper) limits of all controllers have to track the current major (minor) manipulated variable in a small distance e.g., 2 % below (above) the winning MV value.

All controllers are running in automatic mode although only one has access to the actuator. Usually a PI(D) controller, which runs in automatic mode, is in risk of integrator windup if disconnected from the process. The principle of anti-windup logic of the override control is explained in the following example scenario from the application described in section 2.1.

Let's assume the flow controller at the moment writes the bigger manipulated variable and gets in control of the valve from with the maximum preselector. The pressure controller runs in automatic mode and is windup endangered. From the current valve position the low limit of the manipulated variable is dissipated to all controllers.

- If the pressure controller integrates downwards, he stops directly at the low limit derived from the valve position.

- If the pressure regulator integrates upwards, its manipulated variable eventually becomes bigger than that one from the flow controller and it correctly gets in control of the actuator. In this case it becomes the active controller, the windup danger is over, and it specifies indirectly the low limit of the manipulated variable for the flow controller.

With a digital monitoring block, you can display at the operator station which controller is active at the moment.

Control performance monitoring with the ConPerMon block is only provided for the main controller and is deactivated if the main controller is tracking.
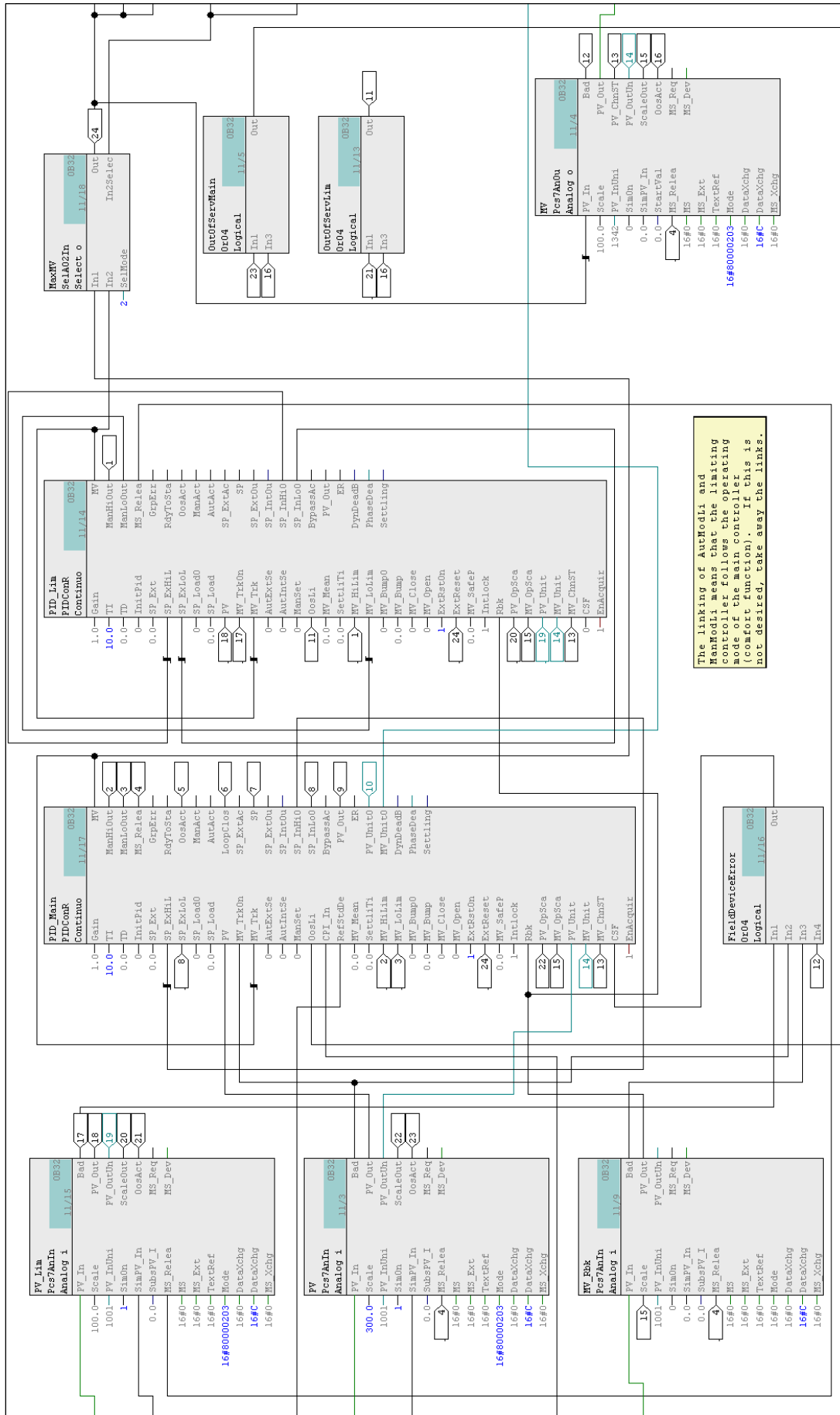
3.2.3. Override Control with PIDConR

Figure 3-5 Override control with PIDConR

The PIDConR is an incremental control algorithm with a serial interactive structure. Incrementally means that the current manipulated variable value is calculated from the old manipulated variable value of the last sample step. Instead of the old manipulated variable value, a starting point (external reset) also can be provided for the manipulated variable calculation from outside by wiring. This property is used for override control according to the principle of selection of manipulated variable.

In the process tag type "Override control with PIDConR" the function is shown. The current manipulated variable value which is sent to the valve (e.g., the maximum MaxMV.Out of the manipulated variable suggestions of main and limiting controller) is used as an external reset ExtReset for both controllers. Therefore, as opposed to override control with all other controllers like PIDConL and selection of the manipulated variable, it is not required to track the manipulated variable limitation (e.g., MV_LoLim) of both regulators in a defined distance (e.g. MaxMV_Minus2.Out) from the manipulated variable value that is sent to the valve.

Both controllers run in automatic mode and calculate a manipulated variable increment starting from the current valve position and suggest a value for the next sample step. The greater suggestion is sent to the process. Nevertheless, the controller whose manipulated variable does not come to effect is not endangered by windup problems because he integrates freely only over the time period of one sample step.

3.3. Commissioning with PID-Tuner

The PID-Tuner can be used for both sub-controllers of an override control as usual, by calculating the parameters of the controllers separately. For the recording of training data and the test of the individual controllers the plant must be driven in two different conditions which are far enough below or above the switchover threshold so that the behavior of the primary and the secondary controller can be monitored and tested separately. Of course, this presupposes that it is possible to define a situation at which the secondary controller is permanently active. Otherwise, the switchover logic must become temporarily deactivated for PID tuning.

3.4. Combination with other APC Functions

Additional functions for the performance improvement of the single controllers, e.g. Gain scheduling, are feasible for override control schemes as well, since they do not impair the behavior of the individual regulator regarding anti windup.

A disturbance feed forward control - if necessary - should be designed separately for the two individual controllers since a disturbance variable certainly has a different effect on the two controlled variables.

With the help of an MPC block a "soft" override control solution can be developed. The control channel for the secondary controlled variable is supplied with a dead band that is wide enough such that the secondary controlled variable is not considered by the MPC until it reaches a critical area. The weighting of the secondary controlled variable in the performance index is assigned a higher value than that of the primary controlled variable such that it really gets higher priority if the critical area is reached. When reaching the critical area, as opposed to a conventional "hard" override control, the primary controlled variable is not ignored completely, but furthermore considered according to the prioritization. Therefore, one can and must call the secondary controller on the plan a little bit earlier already, compared to a hard override control scheme because the "soft" switchover area has a certain width.

4. Simulation Example

Override Control of a Steam Pipeline with Pressure and Flow Control

The plant unit "OverrideSim" in the example project "APL_Example_EU" of PCS 7 Advanced Process Library contains simulation models for flow and pressure control systems with the parameters of the noise generator block.
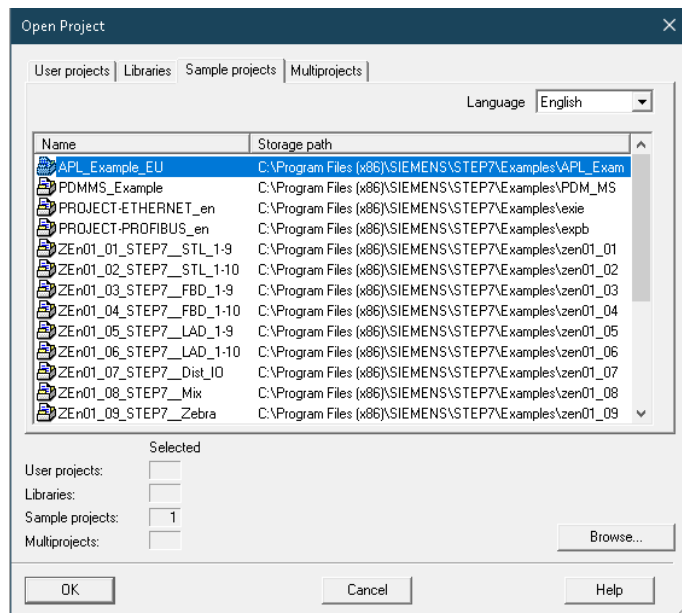

Figure 4-1 Open "APL_Example_EU" sample project

ProcSimC	Flow controlled system	Pressure controlled system
Gain	3	-0,8
TimeLag1	2 s	7 s
TimeLag2	2 s	1 s
PV0	0	80
Noise Variance	0,2	0

Table 4-1: Process parameters of the override control example

The flow-controlled system has typically a positive gain, i.e., when opening the valve, the flow increases, and a relatively short time constant. The flow at valve position 0 (completely closed) is zero.

The pressure-controlled system often has a negative gain i.e., when opening the valve, the pressure decreases if it is measured (in flow direction) in front of the valve. The time constants can be larger and depend on the storage capacity relevant for this pressure and how fast it can be filled, for example by a pump. The pressure at valve position 0 (completely closed) is greater than zero if it is measured in front of the valve.

In this example, the two switchover modes described in chapter 2.2 are implemented.
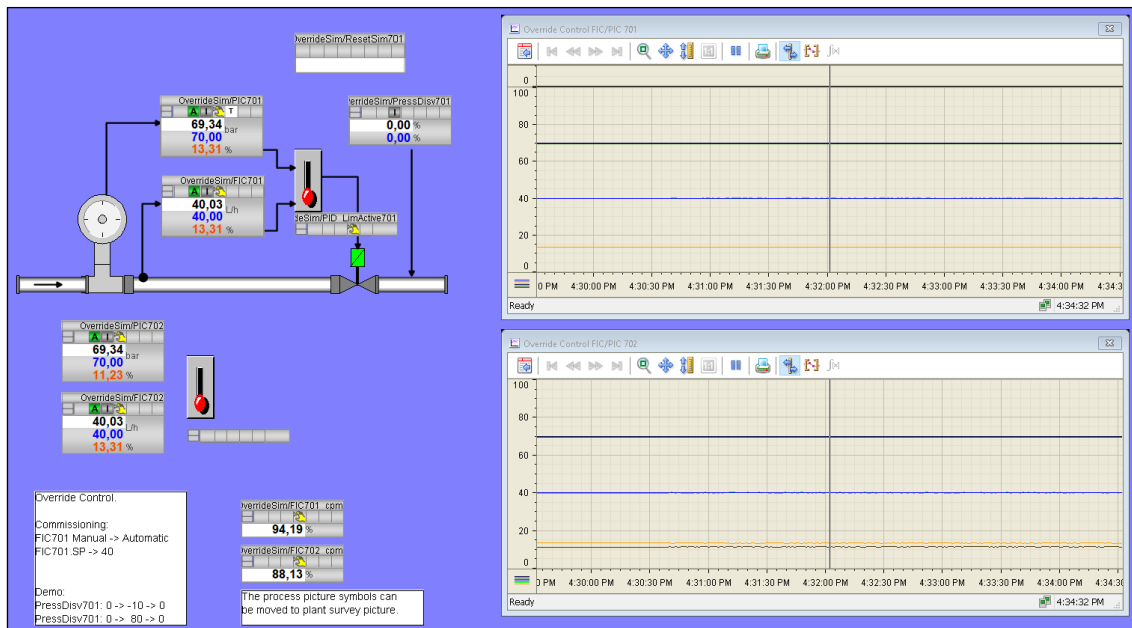
Figure 4-2 Override control for flow and pressure with different switchover criteria

The switchover at the control system represented in the upper part of Figure 4-2 is carried out if the warning limit of the pressure controller is reached. In the lower part of the figure, the controller with the bigger manipulated variable has the priority. With this simulation model, the transitions between the different controllers can be tested.

4.1.   Behavior of the override control scheme for a rise in pressure

In the first application scenario a disturbance takes effect on the pressure i.e. the pressure in front of the valve is raised with the help of the fictitious, operable disturbance variable PressDisv701, closing the valve by about 10% (Figure 4-3).
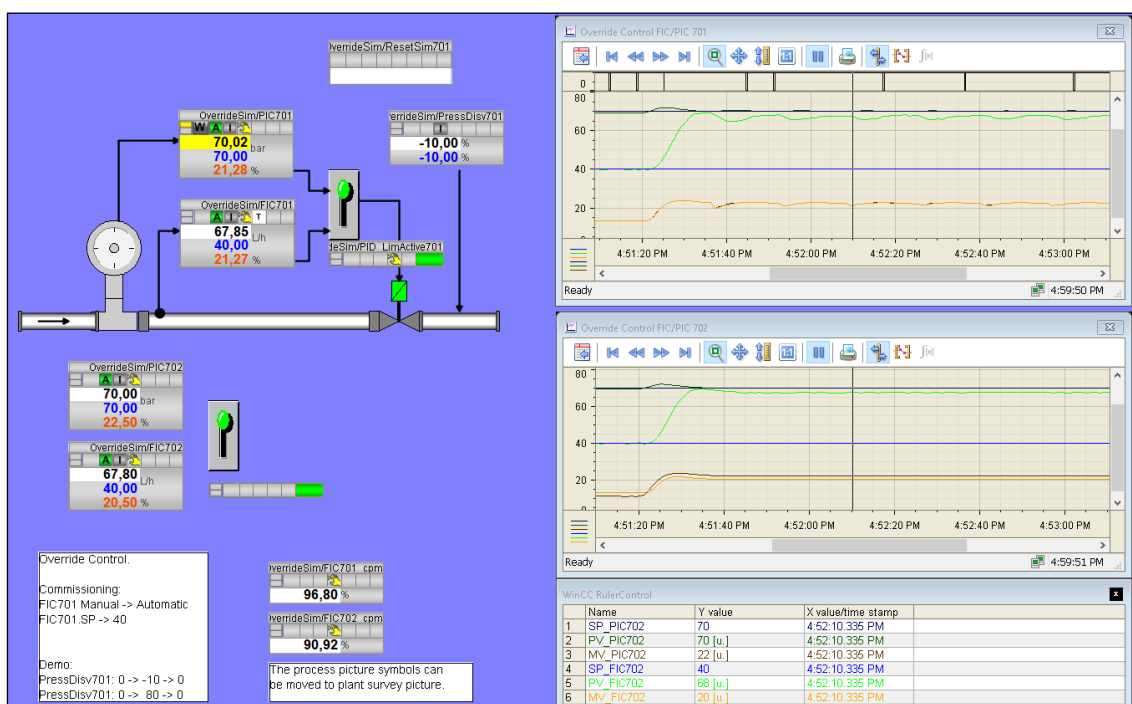

Figure 4-3 Behavior of the override control scheme for a rise in pressure (after approx. 4:51 h)

NOTE	Curves with bright tones (Setpoint ice blue, controlled variable pale green, manipulated variable lager orange) belong to flow control FIC 701/702, dark tones belong to pressure control PIC 701/702. The limiting control scheme (xxx701) is represented in the upper curve window and manages to avoid an increase in pressure above the upper limit value of 70 bar, but you can clearly recognize the limit cycle. The control with selection of the manipulated variable (xxx702) in the lower curve window can prevent the rise in pressure without causing a limit cycle.

In the upper control loop the pressure reaches the upper warning limit of 70 bar triggering switchover such that the pressure controller takes control of the actuator. The controller opens the valve to lower pressure. Since the flow controller is tracking now, the flow increases considerably above the setpoint of 40 l/h without the flow controller acting against it. If the secondary controller must access the actuator, deviations of the primary controlled variable have to accept. As soon as the pressure controller forced the pressure below the warning limit, the flow controller takes control of the actuator again. Since the flow is too big now, the flow controller throttles the valve leading to a pressure rise and starting the game once more. A limit cycle arises but the danger of pipe destruction by overpressure is spellbound. In order to avoid overwhelming the operator with superfluous messages, the text message of the warning limit must be deactivated if the warning limit is used for the switchover logic. The text message of the respective HH alarm limit can (shall) be enabled, since the HH alarm appears only if the override control has failed.

If the same disturbance happens in the lower control system, the pressure controller demands a bigger manipulated variable value, i.e., it wants to open the valve to lower pressure. As soon as the manipulated variable of the pressure controller is bigger than that of the flow controller it takes control of the actuator and opens the valve. Therefore, the flow rises, which in turn causes the flow controller to demand an even smaller manipulated variable. This means that deviations of the primary controlled variable are accepted as soon as the secondary controller takes control of the actuator, similar to the limiting override control scheme. The current state remains stable however, as long as no greater disturbance from outside appears, i.e., no limit cycle arises in this case.

4.2. Behavior of the override control scheme for a decrease of pressure

In the second disturbance scenario the pressure before the valve is reduced, opening the valve (PressDisv701) by around 80% (Figure 4-4).

Figure 4-4 Behavior of the override control scheme for a decrease of pressure (after approx. 5:04h)

NOTE	The limiting controller in the upper curve window manages to keep the pressure above the lower limit value 15 bar, while the override controller with MV selection in the bottom curve is doing nothing against the pressure drop.

In the upper control loop the pressure reaches the lower warning limit and like in the first case, a continuous oscillation begins, in this case at the lower pressure limit. A falling of the pressure further below the warning limit can be avoided. In the lower control loop the flow controller demands a certain manipulated variable value to achieve the demanded flow.

The pressure controller wants to increase the pressure by closing the valve. However, it does not have access to the actuator, since the flow controller calculates the bigger manipulated variable signal. Therefore, the pressure regulator can do nothing against the pressure drop. In this case the current state remains unchanged as well, as long as no greater disturbance from outside appears.

5. Conclusion

Different switchover criteria can be used for an override control scheme. It depends on the given application which switchover logic is favorable. Using the limiting control with selection via controlled variables, a secondary controlled variable can be limited in both directions, preventing violations of upper and lower limits. However, this scheme should be applied only if the secondary regulator is rarely needed. Using an override control scheme with maximum/minimum selection of the manipulated variables, the secondary controlled variable can be limited only in one direction, either protecting upper or lower limits. However, this scheme avoids the limit cycle when the secondary controller accesses the actuator. With the PIDConR block an override control scheme with selection of the manipulated variables can be implemented particularly elegant, using the external reset. This kind of override control is common in the English-speaking control community.

6.   Appendix

6.1.   Service and support

SiePortal

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6.2.   Links and literature

This list is not complete and only represents a selection of relevant literature.

Nr.	Subject
\1\	Siemens Industry Online Support https://support.industry.siemens.com
\2\	Link to this entry page of this application example https://support.industry.siemens.com/cs/ww/en/view/44229396
\3\	SIMATIC Process Control System PCS 7 Advanced Process Library (V9.1 SP2) https://support.industry.siemens.com/cs/ww/en/view/109812806

Table 6-1

6.3.   Change documentation

Version	Date	Modification
V1.0	08/2010	First version
V2.0	10/2023	Revision and Update to PCS 7 V9.1 SP2

Table 6-2