1. Introduction

30 years experience with Sulzer Bypass Systems, including controls and safety functions, show that the bypass-controller is neither a integrated part of the boiler controls nor the turbine controls. The Sulzer bypass system is rather an independent system which serves the operational requirements of the complete plant (i.e. boiler and turbine). The number of active signals between the bypass controller and other systems is small. Much more important is a bypass controller which fulfils exactly the requirements of the bypass operation and allows the easy implementation of safety functions or other quick opening or quick closing functions. The life conserving operation of the heavily stressed valves and pipework, especially by accurate steam desuperheating in all operating modes and transients, poses a special challenge for the Sulzer bypass controller.

2. HP bypass controller

The Sulzer HP bypass controller is an integrated system with the functions signal conditioning, control and valve positioning (Figure 1). The type of operator interface can be tailored to the needs of the individual plant. The below described functions for start up as well as for shut down are fully automated.

With a few standardized interface signals the Sulzer bypass controller can be tied easily into an overall plant automation. The duty of the HP bypass controller can be summarized for the different operating conditions as follows:

- **Boiler start up**

The controller has to control and increase the boiler steam pressure according to the steam production of the boiler. The bypass has to divert the steam flow to the reheater, thus ensuring a proper steam flow through superheater and reheater. The bypass controller has to control the temperature of the steam to the reheater whenever steam is flowing through the bypass.

- **Turbine start up**

The HP bypass controller has to control the steam pressure until the boiler master controller can take over the pressure control.
• **Load operation**

The bypass is closed but the controller is ready to prevent excessive live steam pressure or excessive pressure gradients.

• **Turbine load rejection/trip**

The controller opens the bypass valves, if necessary with the help of the quick opening devices, in order to prevent excessive live steam pressure and controls the pressure until the turbine picks up load again.

• **Safety Function**

Regulations of various countries allow the use of the HP Bypass valves as safety valves for the HP part of the boiler without any additional conventional safety valves on the HP side. For this the HP Bypass has to be equipped with a hardwarewise fully independent safety system. Functionally this system is fully integrated into the bypass controller to ensure smooth transients between safety and control function.

2.1 **Pressure control**

Figure 3 shows in more detail the structure of the pressure controller and the pressure setpoint generator. The different functions and operating modes of the pressure controller are represented again in the start up diagram of Figure 4.

At the begin of a cold start the *minimum opening* ($Y_{\text{min}}$) is active. It ensures immediately after ignition an open path and therefore a steam flow through the superheater and reheater.

When there is enough steam production to reach a predetermined *minimum pressure* ($p_{\text{min}}$) the controller begins to control the live steam pressure by opening the bypass valves.

When the valve positions reach a predetermined value $Y_m$ (determined by the desired steam flow during boiler start up) the setpoint generator begins to increase the pressure setpoint in accordance with the steam production of the boiler, but with a limited maximum gradient.

Figure 2 shows the main elements of a two line HP bypass with the main control functions:

- pressure controller
- temperature controller
- injection water isolation valve control
- safety function
Once the target pressure for starting the turbine \( p_{\text{sync}} \) is reached, the setpoint generator switches to (fixed) pressure control. As the turbine starts to accept steam the bypass will start to close until the turbine consumes all the steam produced by the boiler and the bypass is fully closed.

As soon as the bypass is closed the pressure setpoint tracks the actual pressure plus a threshold \( dp \) which keeps the bypass closed (follow mode). The maximum gradient of the pressure setpoint is still limited. If the life steam pressure exceeds this gradient, the bypass will start to open and the controller returns to pressure control mode. The pressure is controlled by the bypass until normal operation has been restored and the bypass is closed again.

### 2.2 Temperature control

Regarding temperature control it should be mentioned here only that accurate control of the steam temperature under all operating conditions requires a controller well matched to the wide range of operating conditions of a HP bypass (low load, quick opening at full load, etc.). Accurate control of the temperature under all this operating conditions is an important life conserving factor for the heavily stressed walls of the valves and piping.

### 3. LP bypass controller

The Sulzer LP bypass controller is an integrated system with the functions signal conditioning, control and valve positioning (Figure 5). The type of operator interface can be tailored to the needs of the individual plant. With a few standardized interface signals the Sulzer bypass controller can be tied easily into an overall plant automation.

Although independent in operation from the HP bypass controller the LP bypass controller must operate in conjunction with the HP Bypass system and allow the excess steam flow which is not admitted to the turbine to pass to the condenser.

#### 3.1 Pressure Control

The duty of the LP bypass pressure controller for the different operating modes can be summarized as follows:
• **Boiler start up**

The controller has to control the steam pressure in the reheater system. The injection controller has, when ever the LP bypass is open, to control the desuperheating of the steam so that it can be accepted by the condenser.

• **Load operation**

The bypass is closed but the controller monitors the reheat steam pressure in order to open and control the pressure whenever an unacceptable pressure increase is monitored.

• **Condenser protection**

Whenever the condenser is not able to accept the steam or the injection water system is unavailable, the controller has to close the bypass through a separate safe channel in order to protect the condenser.

During load operation the first stage pressure of the turbine serves as load signal for the setpoint generator which generates a load dependent (sliding) pressure setpoint.

With large bypass valves, their flow capacity at high reheater pressure can exceed the absorption capacity of the condenser. For such cases the steam flow to the condenser must be limited by the bypass controller.

If power operated reheater safety valves are provided (e.g. Sulzer MSV valves), coordinated operation of the reheater safety valves with the LP bypass can further improve plant operation for the case of turbine trip or load rejection at high load. The Sulzer LP bypass controller can provide the necessary signals for operation of the reheater safety valves.

3.2 **Injection water control**

Because the steam conditions after the LP bypass desuperheater are usually near or at saturation condition, the temperature after the desuperheater cannot be used as control signal. The necessary injection water flow and valve position of the injection valve must therefore be calculated from the steam flow and steam conditions. The steam flow is in turn a function of the steam conditions and the valve position of the bypass valve. The LP bypass controller provides the necessary computing functions to perform this calculations and uses the calculated injection water demand as setpoint for the water flow controller.
1. **Overview (Diagram D)**

The HP-Bypass Controller consists of the following parts:
- Pressure setpoint generation (Diagrams DA/RA)
- Pressure controller (Diagram DB/TB)
- Temperature controller (Diagram DC)
- Spraywater isolation control (diagram DF)

2. **Pressure setpoint generation**

2.1 **Startup**

2.1.1 **Mode Selection (Diagram RA)**

The “startup mode” is set by the operator or by the signal “Boiler fire on” from the DCS. When the “startup mode” is selected, the setpoint generator can be in three different operating conditions:

- min pressure
- pressure ramp
- restart

The “min pressure” is active whenever the main steam pressure is below “Pmin”.

The “pressure ramp” is active when the main steam pressure is above “Pmin” and below “Psync”.

The “restart” is active when the pressure is above “Pmin” and the BP valve is closed.

The signal “start sequence” is generated when the operating “min pressure” or “pressure ramp” is on.

The “startup mode” is deselected as soon as the pressure reaches “Psync” and the BP valve is open. The “startup mode” is also deselected when the signal “HP Turbine loaded” is active or when the pressure controller is switched to manual.

The “fixed pressure mode” is active when the “startup mode”, the “follow mode” and the “shut down mode” is not active.

The “follow mode” is active when the BP valve is closed and the DEH signal “HP Turbine loaded” is on or the DCS signal “Boiler fire on” is off. or when the. Further the “Follow mode” is on when BP controller is in manual.
2.1.2 Setpoint Generator (Diagram DA)

At startup, with no pressure in the boiler the setpoint generator is in the “min pressure” condition. The pressure setpoint “Ps actual” is then set at pressure value “Pmin”. And the pressure controller open the BP valve to a minimum position value “Ymin” (see: 3. Pressure Controller).

As soon as the main steam pressure is above “Pmin” the “pressure ramp” condition is activated. The pressure setpoint “Ps demand” is increased, whenever the BP valve position “Yset” exceed the position value “Ym”. The increase of the pressure setpoint is limited by the gradient limiter and only positive pressure gradient are allowed during “pressure ramp” operation, decrease of the pressure setpoint “Ps actual” is not permitted in this operation mode.

As soon as the main steam pressure reaches “Psync” the “startup mode” is deselected and the “fixed pressure mode” is activated. The pressure setpoint “Ps demand” is set at the current last pressure setpoint “Ps actual”. In “fixed pressure mode” the “Pressure setpoint” can be adjusted by the operator.

When the “HP turbine loaded” the BP valve will close automatically due to pressure drop. As soon the BP valve is closed the setpoint generator will switch over to “follow mode” (see: 2.2 Load Operation). In this mode pressure setpoint “Ps actual” will follow main steam pressure.

In case of pressurized boiler at startup the “restart” condition is selected while the BP valve is closed. In the “restart” condition the pressure setpoint “Ps actual” is following the main steam pressure but only negative pressure gradients are allowed. As soon as the boiler pressure starts to increase the bypass valve will start to open. When the BP valve open the setpoint generator will go to “pressure ramp” condition if the pressure is still below “Psync” or to “fixed pressure mode” if the pressure at startup is already above “Psync”.

![Diagram DA](chart.png)
2.2 Load Operation (Diagram /DA/RA)

During load operation, i.e. when the HP turbine is taking over all the produced steam, the bypass valves are closed. The “follow mode” is activated. In the “follow mode” the pressure setpoint “Ps actual” is following the actual main steam pressure. The maximum pressure gradient is limited, depending on the actual main steam pressure. A differential pressure “dP” is added to the pressure setpoint “Ps actual” to keep the BP valve closed (see: 3. Pressure Controller).

If the main steam pressure is increasing above the Bypass controller setpoint “Ps actual + dP” the BP valve starts to open. The setpoint generator is switched over to “fixed Pressure mode”.

2.3 Shut down

2.3.1 Mode selection (Diagram RA)

When a plant shutdown is planned the “Shut down mode” can be selected by the operator. The “Shut down mode” can only be selected when the DEH signal “HP Turbine loaded” is active and the BP controller is on auto. As soon as the DEH signal “HP Turbine loaded” is deactivated the “Shut down mode” is deselected and the setpoint generator change to “fixed pressure mode”.

When the boiler shuts down, the DCS signal “Boiler on” is deactivated, the BP valve will close and the setpoint generator is switched to “follow mode”.
2.3.2 Setpoint Generator (Diagram DA)

At “Shut down mode” the pressure setpoint “Ps actual” is following the main steam pressure but only negative gradients are allowed. As soon as the boiler pressure starts to increase the BP valve start to open. After the “Shut down mode” is deselected the setpoint generator is on “fixed pressure mode”. At “fixed pressure mode” the setpoint generator controls the actual pressure. As soon the boiler shuts down the BP valve is closing and the pressure generator is switched to “follow mode”. In “follow mode” the pressure setpoint will again follow the actual main steam pressure.

3. Pressure Controller (Diagram DB)

The pressure controller is receiving the actual main steam pressure signal and the pressure setpoint “Ps actual” from the setpoint generator. It is generating the BP valve position demand signal.

The pressure controller has one M/A station to control the BP valve. At signals “BP open” the BP valve will open to 100%. During this signal controller is set manual and follow the valve position. After the signal the controller set automatic. At signal “BP close trip” the BP valve will be closed by the close command signal to the valve. The controller is set to manual.
In “follow mode” when the “dP on” is active a differential pressure is added to the pressure setpoint “Ps actual” to keep BP valve close.

At “startup mode” when the “min pressure” condition is active the BP valve are opened to a minimum position “Ymin”. The “Ymin on“ is deselected when position is above the minimum position “Ymin”.

4. Fast open / close logic (Diagram TB)

The “BP open” command for the BP valve is generated from DEH signals “Turbine trip” or “Generator switch trip” or when the main steam pressure has reached the quick opening pressure threshold “dp max” above the pressure setpoint “Ps actual”. The “BP open” is blocked when pressure is below the pressure “Pfo” and the “startup sequence” is active or when the “BP close trip “ is active.

The “BP close trip” command is generated when the BP outlet temperature exceed the pressure “Tmax”.

5. Temperature control (Diagram DC)

The temperature controller is receiving the actual signal “HP-BP outlet temperature” from the transmitter and the “Temp setpoint“ set by the operator. The controller is generating the spraywater valve position demand signal. The feed forward signal is generated from “Main steam pressure” and BP valve position and is added to the valve position demand signal. With the adjustable value “wpl” the feed forward signal can be adapted.

The temperature controller has one M/A station to control the sprayvalve BPE valve. The temperature controller is set automatic mode as soon the BP valve is open. When the BP valve closes the spraywater valve closes also, and the temperature controller is set to manual.

6. Spraywater isolation valve control (Diagram DF)

The spraywater isolation valve is open as soon the BP valve is open. When the BP valve is closed the spraywater isolation valve is closed again.
# Parameter list HP Bypass control

<table>
<thead>
<tr>
<th>Function</th>
<th>DWG</th>
<th>Unity</th>
<th>Denom.</th>
<th>Default</th>
<th>Definition/Description</th>
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1. **Overview (Diagram D)**

The LP-Bypass Controller consists of the following parts:
- Pressure setpoint generation (Diagrams DG)
- Pressure controller (Diagram DH)
- Condenser protection (Diagram DM)
- Temperature controller (Diagram DK1/DK2)
- Spraywater isolation control (Diagram DL)

2. **Pressure setpoint generation (Diagram DG)**

In the “min pressure” operation the turbine is not on load. The pressure setpoint “Ps RHH actual” is set to the pressure “Pmin”. The minimum pressure setpoint can also be increased by the operator if an higher setpoint is required.

At “load pressure” operation the pressure setpoint “Ps RHH actual” is generated from the transmitter signal “Turbine 1st stage pressure”. The pressure setpoint “Ps RHH actual” changes in function of the turbine load of the unit.
3. **Pressure controller (Diagram DH)**

The pressure controller is receiving the actual hot reheat steam pressure signal (1 out of 2 selection of two transmitter signals) and the pressure setpoint “Ps RHH actual” from the setpoint generator. It is generating the LBP valves position demand signal.

Each LBP valve has one M/A station.
At signal “LBP close trip” from condenser protection the LBP valves will be closed by the close command to the valves and the controller is set to manual.
The PI controller is set to manual when both LBP valves are set to manual. The controller then is tracking the max valve position.

The maximal LBP valve opening is limited by the steam flow to the condensator. As soon the “LBP steam flow” the LBP valve start to close.

4. **Condenser protection (Diagram /DM)**

The “LBP close trip” command for the LBP valve is generated from condenser protection switches. Each one of the following criteria are activating the “LBP close trip” command:
- Condenser press. high (2 out of 3)
- Condenser temp. high
- Condenser level high
- LBP spraywater pressure low.

5. **Temperature controller (Diagram /DK1/DK2)**

The temperature controller is receiving the actual signal Fw “LBP spraywater flow” from the transmitter. The spraywater setpoint Fws is calculated out of the steam pressure, steam temperature and LBP valve position. The controller is generating the spraywater valve position demand signal.

The temperature controller has one M/A station to control the sprayvalve LP-BPE valve.
The temperature controller is set to automatic mode as soon the LBP valve is open.
When the LBP valve is closed the spraywater valve is also closed, the controller is set to manual.

6. **Spraywater isolation valve control (Diagram DL)**
The spraywater isolation valve is open as soon the LBP valve is open. When the LBP valve is closed the spraywater isolation valve is closed again.
## Parameter list LP Bypass control

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