A-3 Cascade

A-3-1 Description

The following drawings below are provided to help the user to better understand all the information concerning the specific control strategy and, in particular:

- Project Tasks (POU) Organization and Order;
- Block diagram representation;
- Set of display panels used within the application;
- Application examples;
- I/O table related to the signals managed from/to the field.

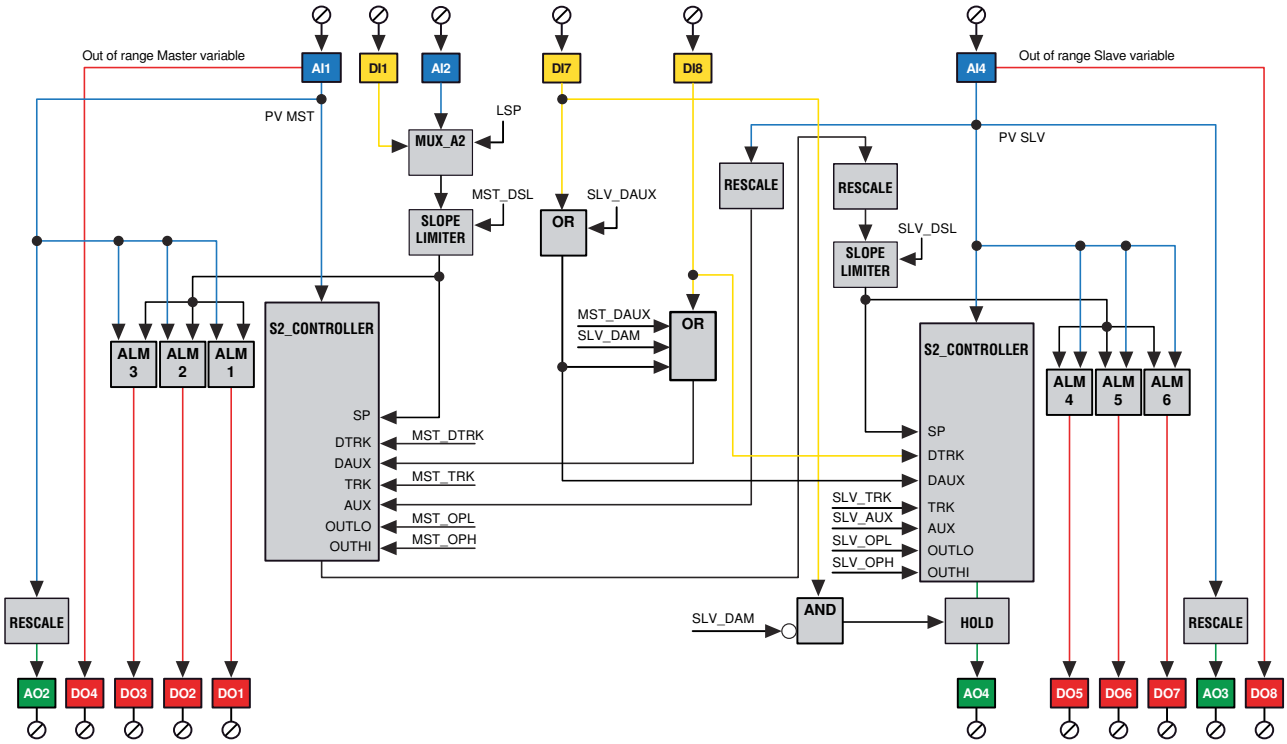
A-3-2 Project Tasks (POU) Organization and Order

In order to obtain the proper operations coming with the functions of the strategy, it is necessary to link the tasks that have been developed as follows:

1. **Cascade_Vars.STD.POE** Global Variables declaration file;
2. **Cascade_Vars.DIR.POE** Direct Variables declaration file;
3. **Cascade_Values_Mngt.ST** Variables application pre-set operations;
4. **Cascade_IO_Mngt.CFC** I/O conditioning operations;
5. **Cascade_Common_Oprs.ST** Application overhall general operations;
6. **Cascade_Loop_Mngt.CFC** Specific Cascade process control operations;
7. **Cascade_Pages.CFC** Overhall display Pages management
8. **Cascade_Tags.CSV** Display pages specific tags excel CSV file.

A-3-3 Block Diagram

The following diagram provides an overall understanding of the process control and logic that have been arranged for the specific purpose. For this reasons the function block representation has been simplified to enhance readability and the specific functionalities meaning.



This configuration consists of 2 loops interconnected in a Cascade configuration and, in particular:

- The Master control loop;

- The Slave control loop.

The Master control output becomes the working SP of the Slave. Additionally have been implemented the following important functionalities:

- Local/Remote SP selection;
- SP Slopes limitation;
- Control Output forcing modes;
- Up to 3 Alarms on the AI1 variable;

The Slave control loop is conceptually a standard PID loop having the following functionalities:

- SP Slopes limitation;
- Control Output forcing modes;
- Up to 3 Alarms on the AI4 variable;

Control

Master Loop

The AI1 Master variable is acquired, filtered, corrected and converted into the desired engineering unit by the specific and dedicated MP_AI_MNGT_ADV function block with out of range detection. Then, it is managed by the dedicated S2_CONTROLLER function block which performs the PID calculation accordingly to the desired SP. The output is then adjusted to the AI4 Slave process variable range by a dedicated RESCALE function block and becomes the working SP into the Slave S2_CONTROLLER module.

Slave Loop

The AI4 Slave variable is acquired, filtered, corrected and converted into the desired engineering unit by the specific and dedicated MP_AI_MNGT_ADV function block with out of range detection. Then, it is managed by the dedicated S2_CONTROLLER function block which performs the PID calculation accordingly to the Master SP. It generates the control output value to drive the actuator which has to be connected to the AO4 analogue output.

The Slave variable is also adjusted to the Master range, by a dedicated RESCALE function block, and connected to the Master loop AUX input. Any of the Slave control output forcing produces a "synchronization" on the Master control loop output. This "feedback" connection is required in order to perform a bumpless refresh in case of Auto/Manual and/or output forcing actions: on every change, the Master output is instantly realigned to the Slave variable value.

Remote Set Point

This feature is supported only on the Master Loop whilst the Slave one is conceptually always in a sort or Remote SP condition. It can be enabled or disabled by using the DI1 digital input. The Remote SP can be selected, by using the dedicated SP_SEL function block, between the standard Local SP, coming from the front panel pages or the analogue input AI2.

DI1 or CASC_xxx_CSP	Selected Value
OFF	Local SP
ON	Remote SP (AI2)

Forcing modes

These operations are alternative to the S2_CONTROLLER PID output calculation. The functionalities provided by the two loops are slight different, as described below.

Slave Loop

The control output forcing mode available within this configuration, selectable through the DI7 and DI8 are:

- **Tracking:** It can be enabled by the activation of the DI4 digital input and it produces as result the control output forcing to the constant value editable from the specific Configuration page.

- **Hold:** It can be enabled by the activation of the DI3 digital input or the DAUX command coming from the dedicated front panel page, and it produces as result the freezing of the control output at the last value calculated at the time before the transition.

DI7	DI8	Selected Value
OFF	OFF	No forcing
OFF	ON	Output Tracking
ON	OFF	Output Hold
ON	ON	Output Tracking

An important point to keep in mind is that the Output Tracking is handled directly by the S2_CONTROLLER function block whilst the Output Hold is managed by a dedicated external HOLD_VALUE one.

Alarms

Master Loop

There are three alarms on the AI1 Master variable, according to the working mode desired for each of the ALARM_ADV function blocks that have been used. The status of each alarm is then reported as digital output through DO1, DO2 and DO3.

The AI1 Out of Range variable status is detected and applied as digital output through DO4.

Slave Loop

There are three alarms on the AI4 Slave variable, according to the working mode desired for each of the ALARM_ADV function blocks that have been used. The status of each alarm is then reported as digital output through DO5, DO6 and DO7.

The AI2 Out of Range variable status is detected and applied as digital output through DO8.

Variable Retransmission

Master Loop

The AI1 Master variable is retransmitted, after a proper rescaling operation, on the AO2 output.

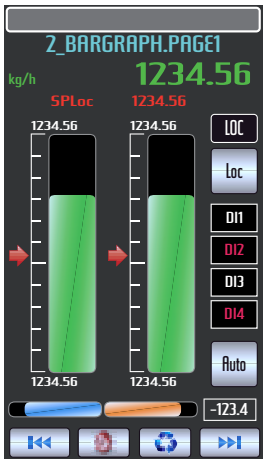
Slave Loop

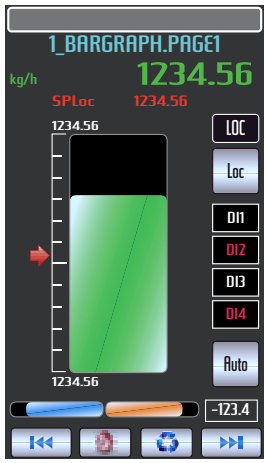
The AI4 Slave variable is retransmitted, after a proper rescaling operation, on the AO3 output.

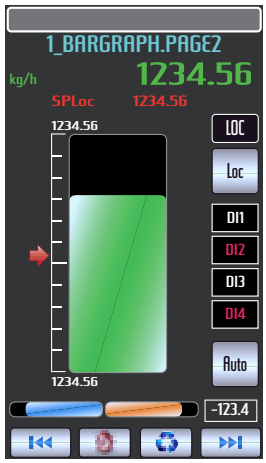
The RESCALE function blocks allow the operator to set the retransmitting output ranges that could be different from the input variable ones. This feature could be very helpful in those cases where it is necessary to partialize an input variable range in order to achieve sensible improvements on the retransmission output resolution.

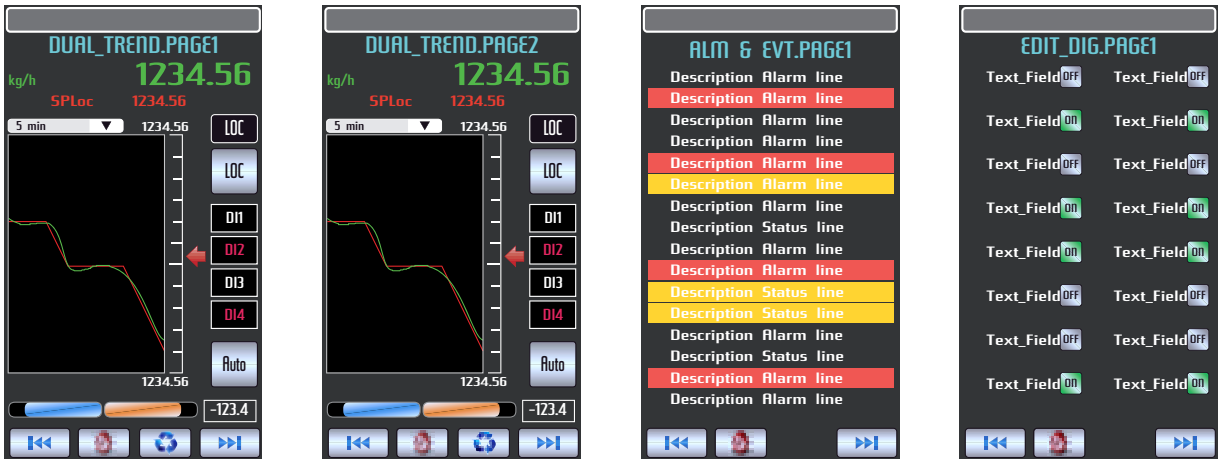
A-3-4 Graphic Displays











The pictures above show the different types of display panels, providing the most effective interface for this strategy configuration. After the Custom page, seven more panel pages consisting in a 2 bargraph display, two single bargraph and two double trend, forcing mode commands plus the alarm list are intended to provide a quite complete interface for this configuration.

Concerning the 2 bargraph display, the Master variable is displayed both at the top, with large size digits, and with the bargraph on the left while the Master Working SP (WSP) is displayed by the slider.

About the Slave loop, the controlled variable is displayed by the bargraph on the right and the Working SP is also displayed by the specific slider.

Both Master and Slave control output, driving respectively the Slave WSP and the external actuator, are displayed by the horizontal bargraph and numerically when the specific loop will be selected.

If you want to operate on a loop, first you have to select it, by pressing the  button. The loop selected is highlighted by the fact that the background colour of the specific Tag changes from dark grey to light blue. Once the loop has been selected, it is possible to change either the SP or the A/M station operating mode. Furthermore, the parameters shown in the upper part of the panel relates to the selected loop.

The alarms status is displayed by the scrolling bar present on top of all the available pages within an application. When an alarm becomes active, the related alarm description scrolls continuously, to alert the operator. Anyway, the operator can get a more detailed view of the alarms, by looking at the specific "Alarms & Events" panel pages.

Additionally, by pressing the  button, in the scrollable top display area, will be shown, in the order, the following variables:

MST_WSP Master loop Working SP;

SLV_WSP Slave loop Working SP.

The SP operating mode is displayed on the top - right area, by side the button which allows to select it. The status and functionalities are related to the selected loop.

The four squared digital indications, on the right side of some panels, are used to indicate some operational status accordingly to the selected loop and, in particular:

1. **TRK** Tracking OP Master loop — **TRK** Tracking OP Slave loop;
2. **AUX** Auxiliary OP Master loop — **AUX** Auxiliary OP Slave loop;
3. **SLP** SP Slope Master loop — **HOLD** Hold OP Slave loop;
4. **KO_AI** Master loop — **KO_AI** Slave loop

These are simple instantaneous indications: for a more detailed description of those, the ALARMS & EVENTS panel page provides univocal information on each of the digital status or forcing actions.

The digital status of an alarm or event is indicated, by type colour, in reverse mode if active or normal mode if inactive.

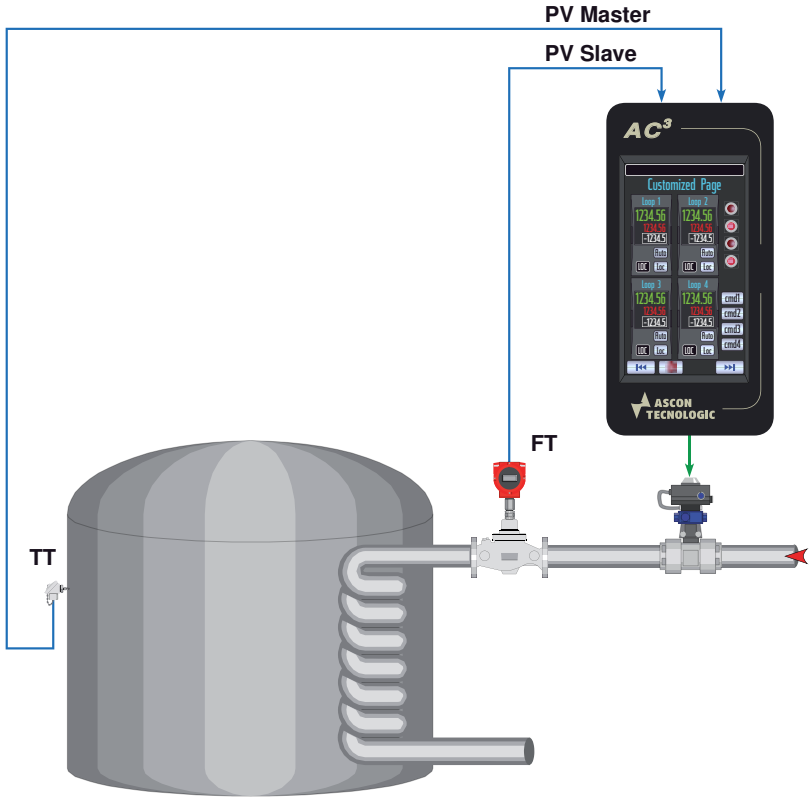
On the ALARMS & EVENTS panel page, the following alarms and forcing status are displayed:

MST ALARM_1	Indicating the Alarm_1 status on the Master loop;
MST ALARM_2	Indicating the Alarm_2 status on the Master loop;
MST ALARM_3	Indicating the Alarm_3 status on the Master loop;
MST AI_KO	Indicating a problem of the AI1 Master input;
SLV ALARM_4	Indicating the Alarm_4 status on the Slave loop;
SLV ALARM_5	Indicating the Alarm_5 status on the Slave loop;
SLV ALARM_6	Indicating the Alarm_6 status on the Slave loop;
SLV AI_KO	Indicating a problem of the AI4 Slave input;
MST OP TRACKING	Indicating the Tracking Output forcing to a value on the Master loop;
MST OP AUXILIARY	Indicating the Auxiliary Output forcing to a value on the Master loop;
SLV OP TRACKING	Indicating the Tracking Output forcing to a value on the Slave loop;
SLV OP AUXILIARY	Indicating the Auxiliary Output forcing to a value on the Slave loop;
SLV OP HOLD	Indicating the Output frozen at the last value on the Slave loop.

Furthermore, this configuration includes also single bargraph display and the double pens trend which provide the same functionalities of the previous panel but, additionally, a programmable time width chart, showing the trend curves of the controlled variables and SP.

A-3-5 Applications

A typical case where a cascade architecture provides excellent results is when the manipulated variable is influenced indirectly by other process variables or external events. An example is shown in the picture below.



The target is to control the tank temperature by managing the hot fluid flow rate to the heat exchanger. This can be achieved, using just one loop, by measuring the temperature of the tank and controlling the flow rate regulating valve of hot fluid. This solution, in most cases, is unsatisfactory because it generates continuous instability on the controlled variable. This is due to the fact the fluid pressure increases and, consequently, the flow rate increases, but the temperature takes a lot of time to rise up in order to have a response on the valve control output. The effect is a big heat accumulation in the tank that creates the instability.

The Cascade control provides a perfect solution in these cases because the Temperature loop, with its slow inertia, is controlled by a separate loop whose output defines the target flow rate of the fluid. This target flow rate becomes the set of the Slave loop controlling the flow rate, that having as measured variable the instantaneous flow rate, is capable to compensate immediately the changes of fluid pressure.

A-3-6 Signals I/O Table

I/O	Terminals	Type	Meaning
AI1	E1 +/F1 -	4... 20 mA	Master Variable
AI2	E2 +/F2 -	4... 20 mA	Remote SP Variable
AI3	E3 +/F3 -	4... 20 mA	Not Used - Available
AI4	E4 +/F4 -	4... 20 mA	Slave Variable
AI5	E5 +/F5 -	4... 20 mA	Not Used - Available
AI6	E6 +/F6 -	4... 20 mA	Not Used - Available
AI7	E8 +/F8 -	4... 20 mA	Not Used - Available
AI8	E10 +/F10 -	4... 20 mA	Not Used - Available
AO1	E11 +/F11 -	4... 20 mA	Not Used - Available
AO2	E12 +/F12 -	4... 20 mA	Master Variable Retransmission
AO3	E13 +/F13 -	4... 20 mA	Slave Variable Retransmission
AO4	E14 +/F14 -	4... 20 mA	Cascade Control output
DI1	A2	NO Digital Input	Master Remote SP selection
DI2	A3	NO Digital Input	Not Used - Available
DI3	A4	NO Digital Input	Not Used - Available
DI4	A5	NO Digital Input	Not Used - Available
DI5	B2	NO Digital Input	Not Used - Available
DI6	B3	NO Digital Input	Not Used - Available
DI7	B4	NO Digital Input	Slave Hold control output
DI8	B5	NO Digital Input	Slave Tracking control output
DO1	A6	NO Digital Output	Master Alarm_1 Status
DO2	A7	NO Digital Output	Master Alarm_2 Status
DO3	A8	NO Digital Output	Master Alarm_3 Status
DO4	A9	NO Digital Output	Out of Range Master variable
DO5	B6	NO Digital Output	Slave Alarm_4 Status
DO6	B7	NO Digital Output	Slave Alarm_5 Status
DO7	B8	NO Digital Output	Slave Alarm_6 Status
DO8	B9	NO Digital Output	Out of Range Slave variable