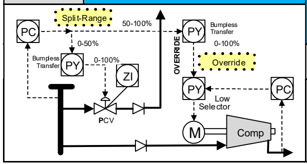
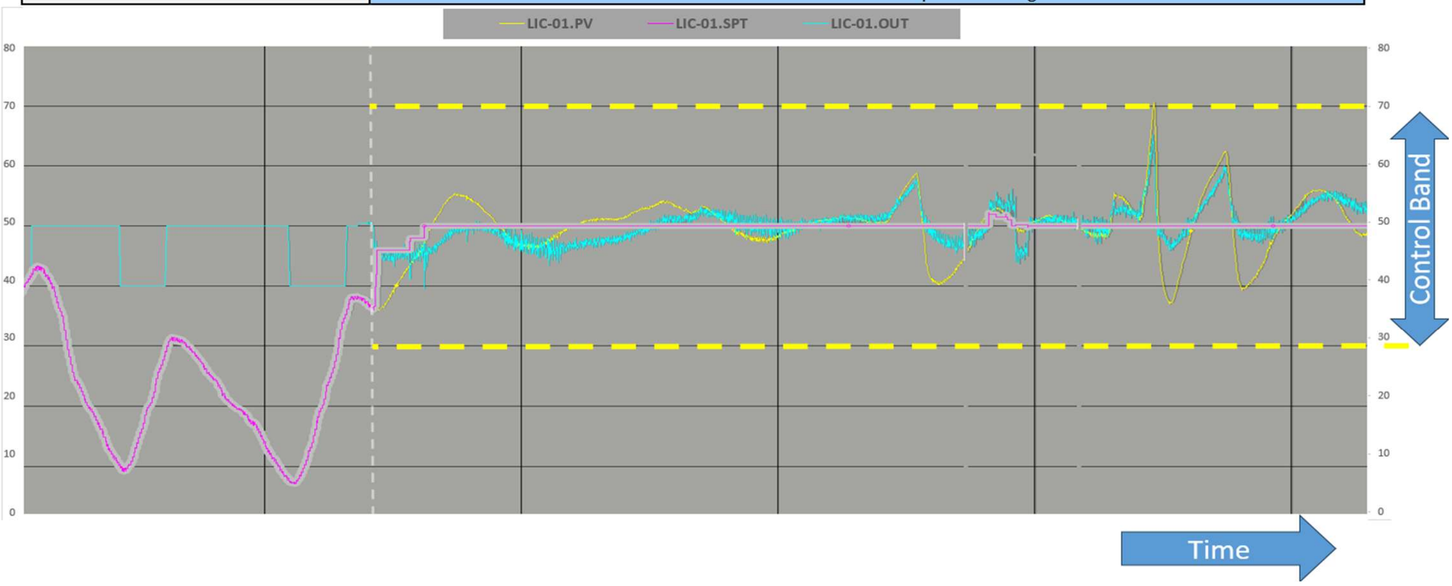


Evidence of Effective tuning for PID industrial controllers

LIUTAIO document 0125B10PL02 Rev.01

Controller does not perform in AUTO mode. Operator keeps controller in MAN mode to manually adjust the process, BUT it is difficult to reach and maintain the desing PV value of 50%.	This is a practical case to tune a PID controller for an **Integrating system**: Previously a plant test was done. Data collection was used to calculate an improved tuning, focusing in maintaining PV value within a ±20% control band around the PV design value of 50%. Next, operator sets the controller in AUTO mode with improved tuning. Now the process runs in AUTO mode, and controller is capable to handle DISTURBANCES within the ±20% control band.
Controller in MAN	Controller in AUTO with Improved tuning



NOTE: this document reinforces the document: (See reference [2])

0125A22PL01 Practical and Effective tuning of PID industrial controllers

Table of Contents

Introduction

In a recent article, a practical and efficient method for tuning PID industrial controllers was discussed.

Refer to https://lnkd.in/gZ82FwPc

The purpose of this article is to provide practical evidence of good tuning for PID industrial controllers, and to explain the “LIUTAIO tuning services” to perform this activity.

In an industrial plant, Operators strive to achieve two main objectives:

1) Maintain the plant operations at normal conditions.

2) Follow operational procedures for Startup, Shutdown, or transitioning between operation modes, typically done manually, unless automatic facilities already exist.

Once the plant is operational, most controllers are usually set to MANUAL mode. Operators then have the option to either retain manual control or switch to AUTOMATIC (CASCADE) mode.

Common findings in scenarios with controllers include:

a) Controllers operating in MANUAL mode due to Operator preference or instability issues in AUTOMATIC (CASCADE) mode.

b) Controller is in AUTO mode, but the tuning or configuration is incentive enough to keep the process in stable condition at normal conditions (typically, control valve in a fixed position). This is described as “Controller in AUTO with MANUAL behavior”.

c) Controller is in AUTO mode, but the process is in permanent oscillation condition.

The implications of these scenarios are:

A) Lack of automatic adjustment to disturbances during plant operations.

B) Increased Operator intervention required to maintain normal plant operations.
NOTE: this statement may not be fully truth for Seft-Regulated processes, unless frequent disturbances happen. But for sure it is true for Integrating processes, since it is not possible to reach stable conditions in MANUAL mode.

In such cases, it is advisable to engage "Professional Tuning Services" to facilitate automatic plant operations. LIUTAIO Consulting and Engineering Services offer expertise in providing these tuning services.

Which is the purpose of LIUTAIO tuning service?

To apply LIUTAIO experience and tools as an Engineering Service to properly tune Industrial PID controllers in a target plant, looking to:

1) Operate the plant in AUTOMATIC, maintaining the normal operation conditions.

2) To allow the control system to AUTOMATICALLY apply adjustment upon disturbances, to enforce the plant normal operation.

Which is the "Added Value" to operate a process plant in AUTOMATIC mode?

Increased Efficiency and Productivity:

- **Optimized Operations:** Automation allows for precise control and monitoring of processes, leading to optimized operations and increased efficiency.
- **Reduced Downtime:** Automated systems can quickly detect and respond to issues, minimizing downtime and maximizing production.
- **Higher Throughput:** Automation can enable faster and more consistent production, leading to higher throughput and increased output.

Improved Safety:

- **Reduced Human Error:** Automation minimizes the risk of human error, which can lead to accidents and safety hazards.
- **Safer Working Conditions:** Automated systems can handle hazardous tasks, reducing the exposure of human workers to dangerous environments.

Enhanced Quality and Consistency:

- **Consistent Product Quality:** Automation ensures consistent product quality by maintaining precise control over process parameters.
- **Reduced Variability:** Automated systems minimize variations in the production process, leading to more consistent and reliable output.

Cost Savings:

- **Reduced Labor Costs:** Automation can reduce the need for manual labor, leading to significant cost savings.

- **Lower Energy Consumption:** Optimized processes can lead to lower energy consumption and reduced operating costs.
- **Reduced Waste:** Automation can improve resource utilization and minimize waste, leading to cost savings and environmental benefits.

Improved Decision-Making:

- **Real-time Data and Insights:** Automated systems can collect and analyze real-time data, providing valuable insights for decision-making.
- **Predictive Maintenance:** Automation can enable predictive maintenance by identifying potential issues before they occur, reducing downtime and maintenance costs.

Other Benefits:

- **Increased Flexibility:** Automated systems can be easily reconfigured to accommodate changes in production requirements.
- **Improved Traceability:** Automation can enhance traceability by accurately tracking products and processes.
- **Enhanced Competitiveness:** By improving efficiency, quality, and safety, automation can enhance a plant's competitiveness in the market.

Overall, operating a plant in AUTOMATIC mode offers significant advantages in terms of efficiency, safety, quality, cost savings, and decision-making. These benefits can lead to improved productivity, profitability, and competitiveness for the plant.

Which is the “Added Value” for LIUTAIO Engineering Service to tune PID industrial controllers?

LIUTAIO applies own experience and tools to perform professional tuning activity with high performance and no oscillations.

See “Tuning examples #1 and #2” in below sections.

We DO NOT GUESS, or apply trial-and-Error, to tune controllers. We collect data from the plant and calculate the required tuning according to the expected or required controller performance. This procedure is executed in minimum time.

Regarding to the plant data, We review historical data, if the necessary data is found, We do not execute plant test to calculate tuning. If the historical data is not consistent for tuning activity, then a plant test shall be executed.

Regarding to tuning calculation, refer to reference [2] for further information.

Regarding to PID controller performance, We verify the calculating tuning, providing Customer evidence of the performance improvement.

LIUTAIO has practical experience executing the tuning activity:

a) In DCS: Honeywell, Foxboro [Schneider, Invensys], Emerson, Yokogawa, ABB, SUPCON, etc.
b) In PLC: Siemens, Triconex, Alen Bradley, HIMA, etc.

In all cases, the procedure to follow is exactly the same one, BUT with adaptation according to the hardware in the plant.

This service requires as a minimum visual inspection of control loop trends. No software, no application, no tools are installed in the customer system.

The Service to tune PID industrial controllers includes:

Turning activity and report

Initially LIUTAIO agrees with Customer the list of controllers to tune.

Next, the “Daily Tuning report” (DTR) is prepared to show Customer every day the tuning activity progress.

In addition, this report indicates previous/actual conditions and remarks describing any improvement or the findings about DCS/Instrumentation issues.

The tuning activity is organized together with Operation team, in order to schedule the most appropriate time for execution.

Operation team is responsible to schedule the time-window, and required documentation/permits, to perform the tuning activity.

In practice, depending on the working dynamic with Operation team, it should be possible to tune 5-10 controllers per day.

DCS and Instrumentation issues report

When DCS or Instrument issues are found, LIUTAIO representative analyses the issue.

“Daily Tuning report” (DTR) is updated accordingly to report the issue.

In the case the issue is complex, LIUTAIO representative will prepare an “Tuning Issue Report” for proper documentation.

LIUTAIO representative will collaborate with Customer to solve the issue, and to explain the situation to other disciplines/departments, and to suggest the possible solutions.

Troubleshooting analysis report

For DCS/Instrument complex issues, LIUTAIO representative will prepare a “Troubleshooting analysis report” to properly explain the issue, and to suggest possible solutions.

Further explanations

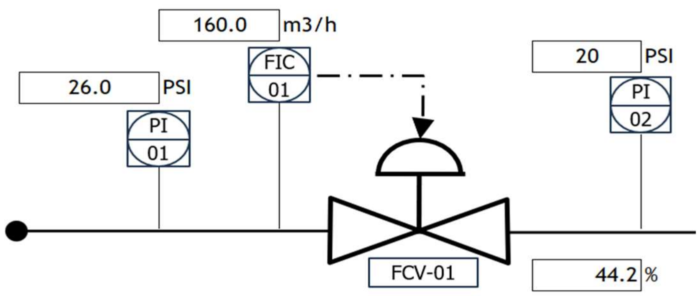
About the LIUTAIO tuning services for PID industrial controllers.

Tuning Example #1 – Self-Regulated process

The purpose of this example is to show a typical low performance flow controller in a plant, and to describe how the controller performance improves after LIUTAIO tuning activity.

Notice that the main point for this example is that a flow process is most of the time a stable process, regardless of if the related controller (with poor performance) is in MAN or AUTO mode,

Figure 1 – Process scheme for tuning example #1



Error! Reference source not found. shows the process for this example. It is a plant feed flow control scheme.

The plant feed flow is controlled with flow controller FIC-01, which manipulates the flow control valve FCV-01.

The process requirement is to operate at 160 m3/h feed flow, and to maintain that flow even under pressure disturbances.

.Figure 2 shows a trend with the flow controller FIC-01 typical performance, and next improvement after LIUTAIO tuning activity.

Figure 2 – FIC-01 and PI-01 process trend for tuning example #1

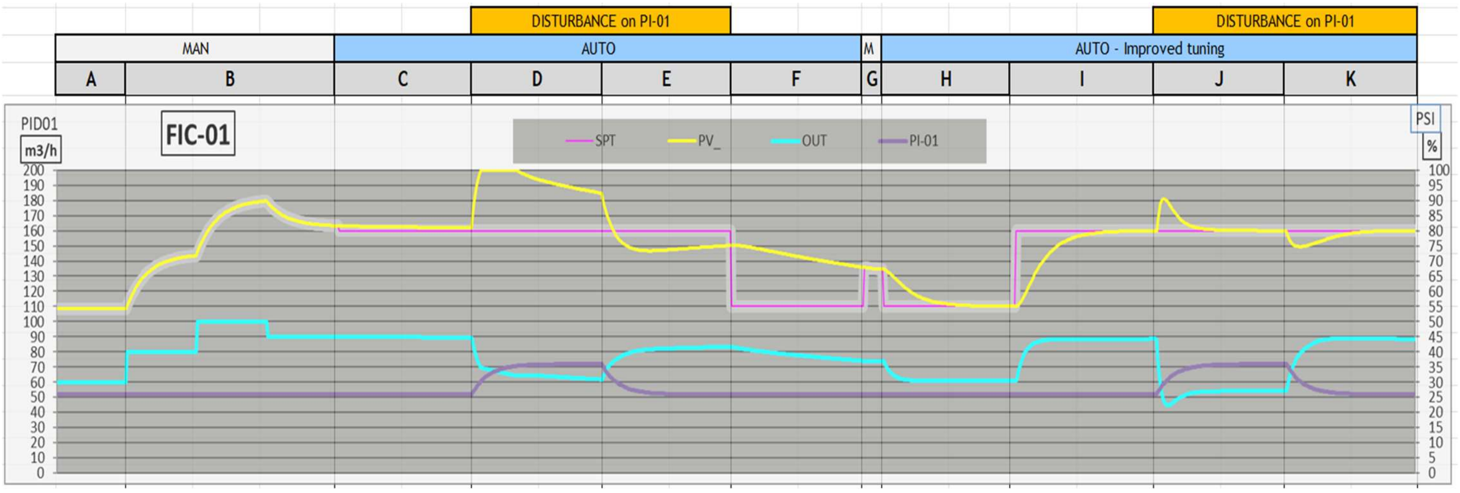


Figure 2 shows:

a) Variations in FIC-01 output (OUT), PV and setpoint (SPT) values. Also, it is shown the variation in inlet pressure PI-01.
b) Left vertical axis corresponds to FIC-01.PV and SPT values.
c) Right vertical axis corresponds to the FIC-01.OUT and PI-01 values.
d) Botton time axis is not shown to simplify the trend.
e) At the trend top, the total trend time is distributed in several time labels from “A” to “K”.
f) In which time labels, the controller FIC-01 is in AUTO or MAN mode.
g) In which time labels, the inlet pressure DISTURBANCES appear.

Table 1 describes the process variations, operator actions and controller performance in Figure 2.

Explanation is organized according to the column labels "A" to "K" in Figure 2.

Table 1 – Description of process variations in Figure 2 trend

Column Label	Process description on each label.
A	Plant feed flow is stable at 110 m3/h. FIC-01 is in MAN mode, active PVtracking and controller is working with typical tuning in the plant. Operator can manually manipulate flow control valve FCV-01.
B	Operator manually opens the FVC-01 from 30% to 40%, 50% and 45%, to reach the feed flow of 160 m3/h.
C	At the beginning of label "C", operator sets FIC-01 in AUTO mode, and set its setpoint value to 160 m3/h. FIC-01 flow controller maintains the flow very near to the target, but it does not fully reach the target value of 160 m3/h. This situation is assumed as normal in many plants, and operator expectation is satisfied.
D	At beginning of label "D", a DISTURBANCE happens, making PI-01 inlet pressure to rise, and feed flow therefore also increases. In this situation, flow increase is too big, so, operator should set FIC-01 in MAN mode to close FVC-01. Of course, something as described shall happen, but in this example the controller FIC-01 is kept in AUTO mode to show the poor performance to handle the DISTURBANCE.
E	At beginning of label "E", a DISTURBANCE develops decreasing PI-01 inlet pressure, and feed flow therefore also decreases. In this situation, FIC-01 performance is still low, and controller is not capable of handling the DISTURBANCE.
F	FIC-01 is still in AUTO mode. Operator sets FIC-01 setpoint (SPT) value to 110 m3/h. Notice that FIC-01 performance is still low to reach the new SPT target value. Controller behavior is near to the condition "Controller in AUTO with MANUAL behavior". **NOTE:** FIC-01 flow controller should be fast enough to handle DISTURBANCE, keeping process as close as possible to normal operation condition.
G	FIC-01 is temporary set in MAN mode to change its tuning to the one calculated by LIUTAIO for better performance. Notice, since controller PV tracking function is active, the FIC-01.SPT value changes to match this controller's PV value.
H	Operator sets controller FIC-01 in AUTO mode, and changes setpoint (SPT) value to 110 m3/h. In comparison with label "F", now the controller performance is improved, making controller PV to reach the target SPT value within the label "H" time.
I	Operator sets controller FIC-01 setpoint (SPT) value to 160 m3/h. The controller performance is also improved, making controller PV to reach the target SPT value within the label "I" time.
J	At beginning of label "J", a DISTURBANCE happens, making PI-01 inlet pressure to rise, and feed flow therefore also increases. In comparison with label "D", in label "J" situation and after improved controller tuning, the FIC-01 controller is capable to handle the DISTURBANCE, making the controller PV to stay as close as possible to the target SPT value within the label "J" time, with minimum deviation and for short time.

Column Label	Process description on each label.
K	At beginning of label “K”, a DISTURBANCE develops decreasing PI-01 inlet pressure, and feed flow therefore also decreases. In comparison with label “E”, in label “K” situation and after improved controller tuning, the FIC-01 performance is GOOD, and capable to handle the DISTURBANCE, making the controller PV to stay as close as possible to the target SPT value within the label “K” time, with minimum deviation and for short time.
CONCLUSION	After LIUTAIO tuning activity, the feed flow controller FIC-01 tuning was improved, and now this controller is performing in AUTO mode, making the PV value to reach the controller setpoint target, and properly handling DISTURBANCES.

Tuning Example #2 – Integrating process

The purpose of this example is to show a typical low performance level controller in a plant, and to describe how the controller performance improves after LIUTAIO tuning activity.

The main difference with “Tuning Example #1” is that level controller in this example is applied to an “Integrating process” that is not stable upon DISTURBANCES when the level controller is in MAN mode.

Figure 3 – Process scheme for tuning example #2

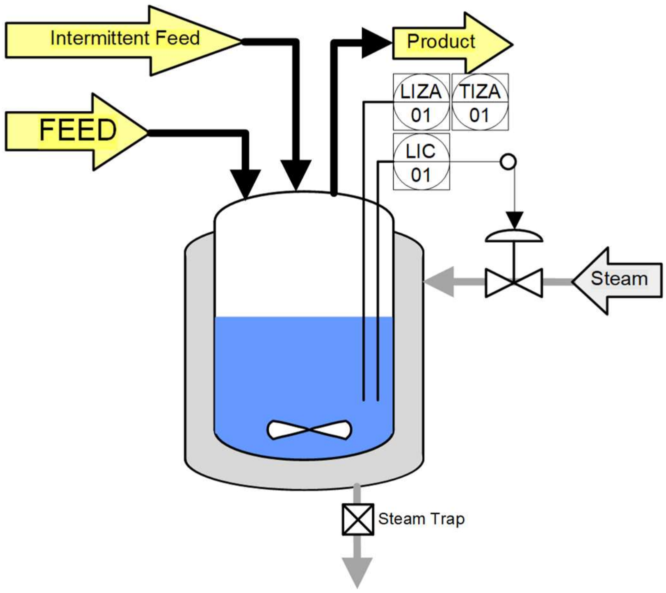


Figure 3 shows the process for this example. It is a continuous liquid phase reactor.

Main FEED flow is relatively stable, and there is a 2nd intermittent feed flow. Reactor outcome is at top. Steam flow is the heating medium with variations.

Normal Design operation level is 50%.

There is a level trip at 80%, and a temperature trip. Design indicates that a level trip has higher probability to come first than a temperature trip.

Since reactor level exhibits frequent/high variations, operator experience indicates that LIC-01 cannot perform. So, operator keeps LIC-01 permanently in MAN mode and level is controlled manually in a range between 5% to 50%.

Below Figure 4 and Figure 5 show trends for the level controller LIC-01 in MAN mode, and improvement after LIUTAIO tuning activity.

Figure 4 and Figure 5 show:

a) Variations in LIC-01 output (OUT), PV and setpoint (SPT) values.
b) Left vertical axis corresponds to LIC-01.PV and SPT values.
c) Right vertical axis corresponds to the LIC-01.OUT value.
d) Botton time axis is not shown to simplify the trend.
e) At the trend top, the total trend time is distributed in several time labels from “A” to “E”.
f) In which time labels, the controller LIC-01 is in AUTO or MAN mode.

Table 2 describes the process variations, operator actions and controller performance for Figure 4 and Figure 5.

Explanation is organized according to the column labels “A” to “E” in Figure 4 and Figure 5. The time frame for these time labels match in both figures.

Figure 4 – LIC-01 process trend for tuning example #2 (1 of 2)

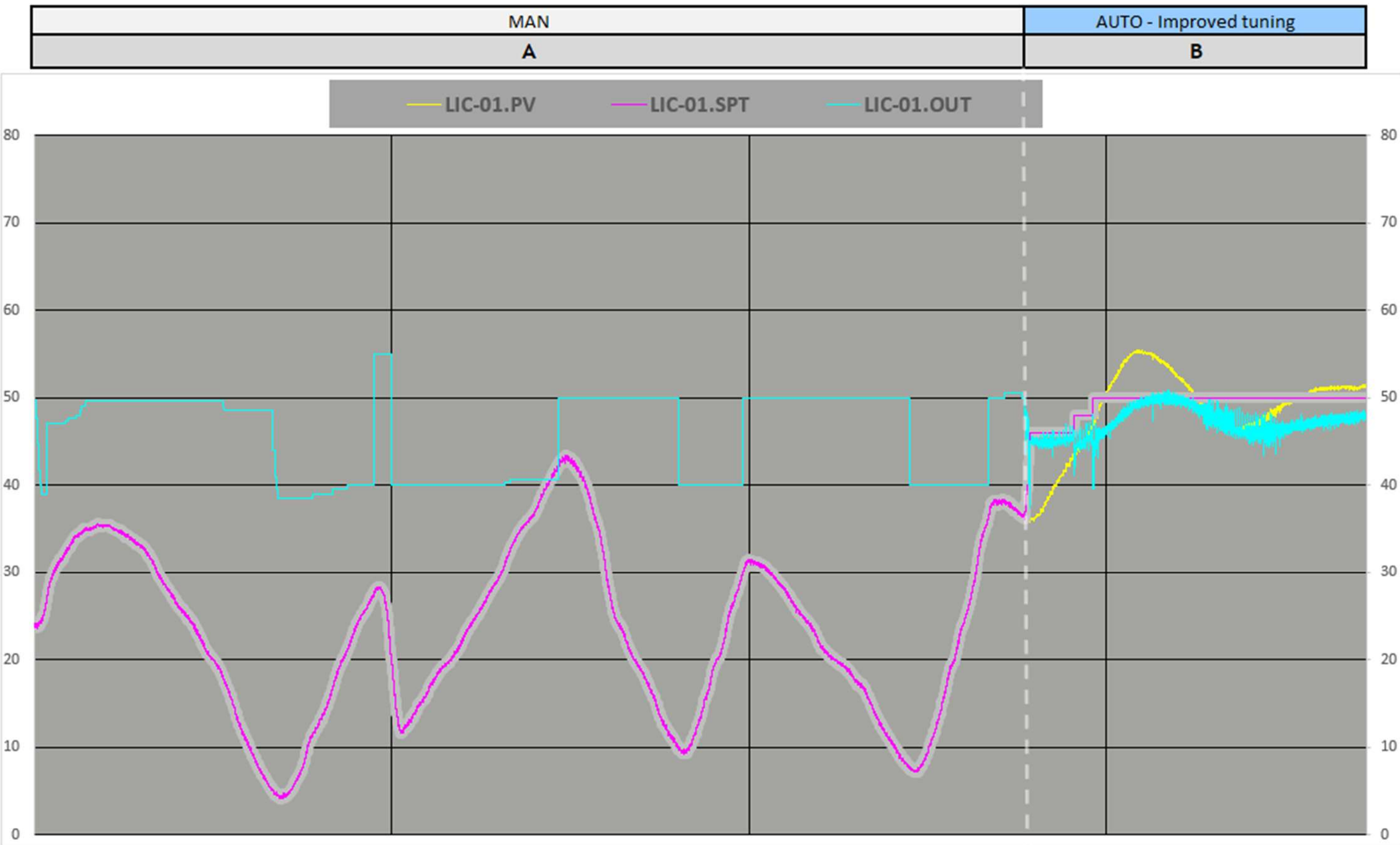


Figure 5 - LIC-01 process trend for tuning example #2 (2 of 2)

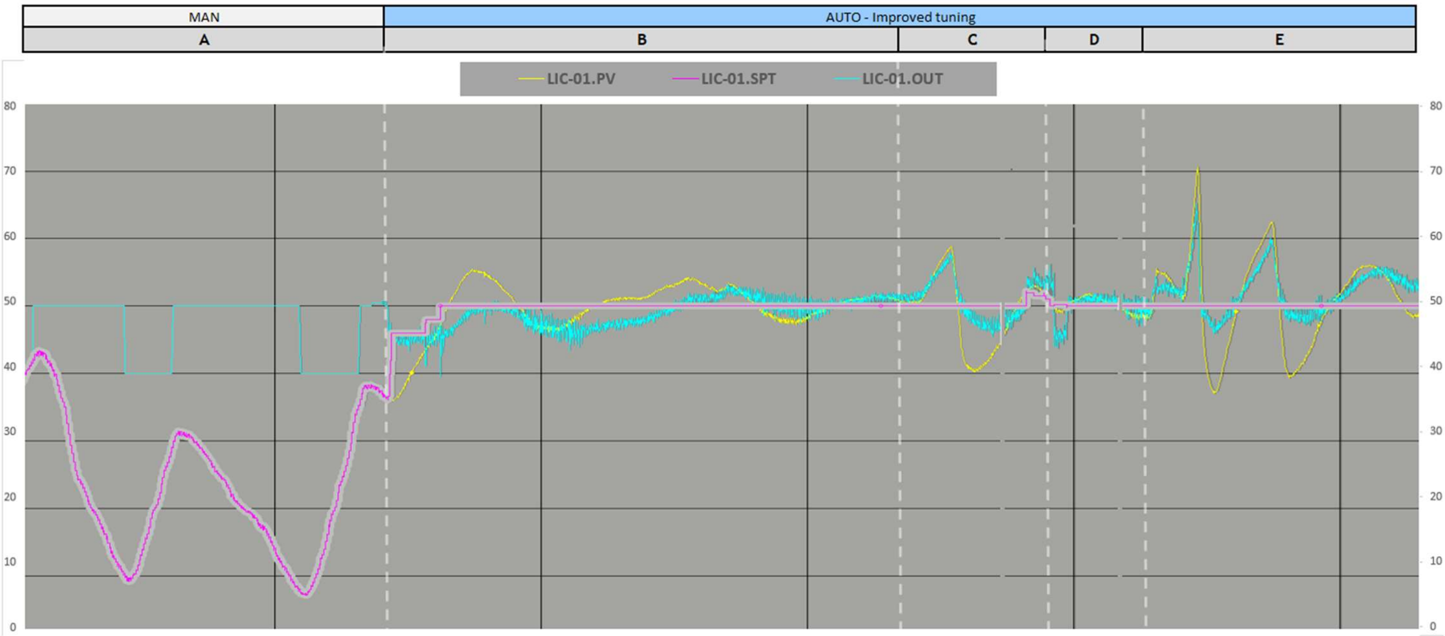


Table 2 - Description of process variations in Figure 4 and Figure 5 trends

Column Label	Process description on each label.
Before A	As described previously, operator keeps LIC-01 in MAN mode, because this controller has never performed as requiured. Since the level control is an integrating process for the plant as shown in Figure 3, it was expected frequent operator intervention to keep LIC-01.PV within the range 5% to 50%. PVtracking function is enabled for LIC-01. Initially, a review of history data was done to identify if step test data can be collected from operator activity, but it was found that the history data was not good. The procedure to follow to execute the tuning activity was explained to the operation team. A step test was required as described in reference [2]. It was decided to execute the step test for LIC-01. Operator attitude was sensitive to perform the step test, and the operator interrupted the activity many times. Finally, step test was completed, and the improved tuning was calculated. Nevertheless, the activity finished near the end of the operator shift, and it was decided to continue next day.
A	Next day, last night history data was reviewed, and it was found that to keep the LIC-01.PV within the range 5% to 50%, the operator actions were similar to the step test procedure. Improved tuning was calculated again with this data, and the result matched calculation in previous day. **NOTE:** since the level control is an integrating process, and based on the data collected, frequent DISTURBANCES will affect the operation. So, LIC-01 in AUTO mode with existing tuning cannot make PV value to be near to SPT value. Refer to tuning example #1 for typical controller behavior when a DISTURBANCE happens. The LIUTAIO tuning procedure calculates the improved LIC-01 tuning values to allow level controller LIC-01 to maintain the reactor level within a PV control band. Since there is a level trip at 80%, it was agreed that a reasonable PV control band shall be ±20% around the design operation setpoint of 50% level. Improved tuning was calculated accordingly. This means that improved tuning will keep level within the control band.
B	At this time, improved tuning was already applied to level controller LIC-01. At beginning of label "B", operator sets level controller LIC-01 in AUTO mode, and slowly changed controller setpoint up to 50% value, in order to match the design level. Figure 4 shows that level controller LIC-01 started to reduce variations of the reactor level, in comparison with trend in label "A". Figure 5 shows remaining label "B" time and it can be observed that level controller LIC-01 is performing in AUTO mode.
C	A DISTURBANCE was developed, and level controller LIC-01 performed as expected keeping the reactor level ±20% around the design operation setpoint of 50% level.
D	Within label "D", it looks like that DISTURBANCE effect was low, and reactor level remained very close to design operation setpoint of 50% level.
E	A DISTURBANCE was developed, with greater magnitude in comparison with DISTURBANCE in label "C". Level controller LIC-01 performed as expected, keeping the reactor level ±20% around the design operation setpoint of 50% level.
CONCLUSION	After LIUTAIO tuning activity, the level controller LIC-01 tuning was improved, and it was possible to set controller performing in AUTO mode, keeping the reactor level ±20% around the design operation setpoint of 50% level, regardless of the plant DISTURBANCES.

Q&A

1) Why is it important to properly tune Industrial PID controllers?

The purpose of PID controllers in the industry is to keep production processes in the normal operation condition, and to automatically regulate such processes upon disturbances, looking for automatic recovering stable operation at the adequate/fast response time.

2) In practice, what is the nowadays condition of Industrial Controllers?

Despite the PID controllers' purposes, in practice it is common to find controllers in one of these states:

a) Controller operates in MAN mode, instead of AUTO (or CAS mode). Operator has more confidence keeping operation in MAN mode.

b) Controller is in AUTO mode, but the tuning or configuration is incentive enough to keep the control valve in a fixed position. This is described as "Controller in AUTO with MANUAL behavior".

c) Controller is in AUTO mode, but the controlled variable is in permanent oscillation condition.

Therefore, in nowadays real life, automatic regulation for stable operation is poor or inexistence.

3) Can LIUTAIO methodology for "Professional Tuning Service" of PID industrial controllers be applied in old and new control loop installations?

For the LIUTAIO "Professional Tuning Service" of PID industrial controllers, the minimum requirement is visual inspection of control loop trends.

No software, no applications, and no tools will be installed in the customer system.

It does not matter if the trend is in a DCS or circular paper.

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