Tuning loop: control performance and diagnostics

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Summary

This article intends presenting an innovative solution for controlling the performance of tuning loops. The software product has been designed to enable process managers to recover profit margins through the systematic monitoring and adjustment of the performance of the basic control system. To achieve this aim, technologies and methods are systematically used that have been developed in research and development laboratories on the basis of the results produced over the past 15 years in the fields of control engineering and information technology.

Keywords: Control performance monitoring, loop tuning optimization, model identification

1 INTRODUCTION

Ever since the early 90s, there has been a renewed and careful interest in the evaluation of basic control loop performance. This has been caused by the contemporaneous existence of two stimulation factors, one academic and the other economic/managerial.

On the one hand, the work of Harris [1], has re-launched a field of research that had seemed to be gradually losing ground, presenting a simple and effective method for the objective evaluation of tuning loop performance, with a measurement that can be compared with the determination of the "*state of form*" of the loop. At the same time, there has been increasing attention in the field of continuous processes towards the careful management of basic control systems. In other words, there has been a growing awareness of the impact these have on production processes, both directly and as a binding condition for the effectiveness and relevant economic return of more sophisticated automation strategies.

The growing demand has naturally been intercepted by industrial automation suppliers who continue to be engaged in developing and marketing products and solutions for monitoring tuning loop performances.

The successful application of these products depends on a series of factors that go beyond the pure effectiveness of the calculation algorithms of the various loop performances, including the ability to connect up without disturbing the system forming the subject of the evaluation, easy use and configuration and the possibility of translating the inevitably obscure figures into a concise number of precise data useful for the control room operator or maintenance engineer.

Nevertheless, even a punctual and accurate diagnostic capacity is often not enough. The drastic reduction of the workforce on production sites does in fact force the professional figures in charge of operations to take on several diverse duties and consequently the need arises not only to identify the nature of the problem but to also be able to solve it with quick, safe and easily implemented remedial measures.

This work intends presenting a number of solutions recently placed at disposal by the market in the form of a product that combines monitoring and diagnostic functionality with instruments for effectively intervening on the control system in order to restore it to optimal operating conditions.

The article is organised as follows: after a short historical digression on the basic principles of control system performance monitoring, section 2 focuses on the requirements, the restraints and the opportunities which the application of these techniques offers in the field of process automation. Section 3 is dedicated to the description of the salient aspects of the proposed solution, while section 4 supplements the treatise with a short example of application. Finally, section 5 is dedicated to future prospects and scheduled improvements.

2 EVALUATION OF CONTROL SYSTEM PERFORMANCES: STATE OF THE ART

The availability[1] and effectiveness of a control system is clearly important for managing the process in conditions of safety and maximum performance, ensuring quality of production and its profitability.
Over 90% of the process control systems are based on PID type controllers, which represent a basic standard[2] as regards process tuning.

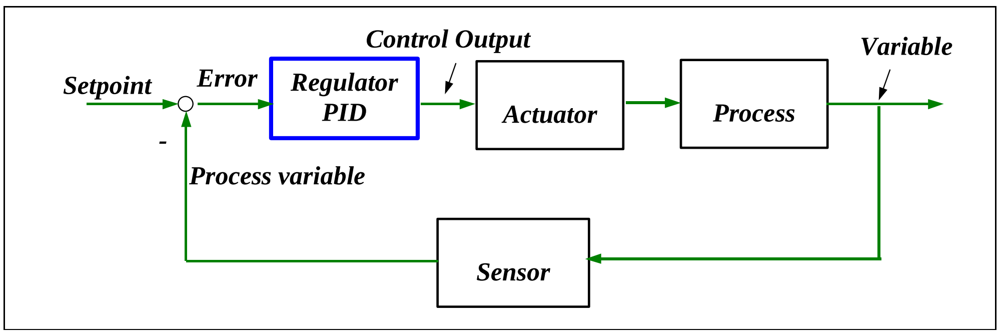

Figure 1 - Tuning loop with PID diagram

These controllers, the basic principle of which is fairly simple, represent the basis of any automation strategy, including in the case of second level systems, such as multivariable controllers or MES (*Manufacturing Execution Systems*).
The most general expression of the algorithm of the PID controller consists in the so-called "parallel" expression, in which the three proportional, integral and derivative parts operate in a non-interacting way on the feedback error. Including the possibility of a weight factor on the proportional part and of a derivative action on the process variable or on the error, this can be written as follows:

$$\mathbf{u} = \mathbf{K_P}(\boldsymbol{\beta}\cdot\mathbf{r}-\mathbf{y}) + \mathbf{K_I}\frac{\mathbf{1}}{\mathbf{s}}(\mathbf{r}-\mathbf{y}) + \mathbf{K_D}\frac{\mathbf{s}}{\mathbf{1}+\mathbf{T_F s}}(\boldsymbol{\gamma}\cdot\mathbf{r}-\mathbf{y})$$

where:

u	Manipulated Variable (Controller action)
r	Setpoint
y	Process Variable (Controlled Variable)
K_P	Proportional Gain
K_I	Integral Gain
K_D	Derivative Gain
T_F	Time constant (Filter)

[1]By the word *availability* is meant in this case the relation between the time the loop is able to operate in closed chain with appropriate performances compared to the total operating time, including therefore the open chain operating time.
[2] Notice that, though the PID concept is fairly widespread, its practical implementation in the various control and automation systems is very varied, presenting different variations.

β Setpoint weight factor in proportional part [3]
γ Setpoint weight factor in derivative part [4]

The parameters K_P, K_I e K_D represent the "knobs" at the disposal of the control engineer which permit combining the characteristics of the controller with the actual dynamics of the process to be governed, so as to obtain the required answers and behaviours. We thus found ourselves faced with a system with 3 distinct degrees of liberty for which the best value threesome must be pinpointed. Because the overall process performances will depend on the goodness of the tuning done, it follows that this appears as the crucial step in commissioning a plant. For this reason, it is normally entrusted to specialists who enter the optimal values of the three parameters on the basis of empirical rules or principles based on personal and therefore not easily transferable experience.

With the passing of time however, changes in production conditions or normal settling of component parts, sensors and actuators can affect the effectiveness of regulation. These changes can vary from changes in process gain or dynamics, to valve operation problems (*stiction*[5], hysterisis) to the application of restraints on operating conditions. The moving away from original *tuning* conditions would therefore call for the periodical retuning of the controllers, so as to adapt tuning to changes in operating conditions[6].

Monitoring and restoring the operation of the entirety of plant controllers is however a pretty onerous business as regards personnel commitment. More specifically, such requirement clashes both with the considerable reduction in staff under way for some time now in all production sites, and with the scarcity of people truly expert in the field of control system tuning. The lower availability of time and resources inevitably leads to neglecting major aspects of process management which nevertheless have an impact on the global economical bill. Part of this category are the maintenance requirements of regulating instruments and parts. Persistent temperature fluctuations caused by a valve in hysterisis or a badly tuned controller will have to be offset by the continuous use of hot and/or cold fluids, the cost of which will accumulate in an insidious but not negligible way on the energy bill and consequently on variable production costs [2].

A further contribution to the drop in economic performance also comes from the objective difficulty of tuning procedures. A very high percentage of industrial controllers does in fact lack the derivative part by need rather than by choice. In practice, the decision is made not to use a PID controller not on the basis of a comparative analysis of performances (which at least in the case of processes distinguished by second order or superior dynamics, would be far better) but due to the extreme difficulty of manually tuning a system with three independent parameters [3]. In other words, the lack of mathematical supporting instruments translates into the resigned acceptance of lower performances.

In practice, we are faced with a situation distinguished by [4]:

- from hundreds to thousands of loops
- system complexities (both process and automation)
- multiple and sometimes contrasting control goals
- long maintenance cycles
- low availability of operating and engineering personnel
- severe economic impact

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[3] For β=0 the proportional part acts on the PV while for β=1 it acts on the deviation
[4] For γ=0 the derivative parts acts on the PV, while for γ=1 it acts on the deviation.
[5] The English term *Stiction* identifies all those events due to friction on the valves
[6] It should be noted that this type of problem can in some cases can be completely inherent in the specific type of production and not relate to the history of the unit and *equipment.* This is the case of plants working with *campaign productions* (frequent in fine chemistry) where the load conditions and the type of product can be greatly different from one period to another, leading to the need for personalised tuning for the different production campaigns.

The existence must be emphasised of a perception problem on the part of the management, ready to acknowledge the positive economic impact of cutting back the number of staff, but less inclined to accept the actual drop in margins caused by failure to maintain the process at potential efficiency levels. This leads the company management to focus on production efficiency increases tied to cuts in the number of staff, while underestimating the benefits produced by better management of company assets.
Hence the need to have instruments and methods able to keep a check on the performance of controllers, warning and requesting human assistance only when actually required [5].
To cater for this need, in the past 15 years, strong research and development efforts have made it possible to develop a series of methods for monitoring control loop performances essentially based on the evaluation of variance in the controlled variable in the face of stochastic disturbances than cannot be measured ([6], [7]).
Most of these methods are based on the work of Harris [1], who suggested using the closed-loop collected data to assess controller performances using the so-called minimum variance control (MVC) as an objective benchmark.
Without going into technical details, which do not fall within the scope of this work (for more details see, among others, the excellent survey provided by [8]), it will be enough to recall that, from a theoretic viewpoint, a minimum variance controller is a controller able to remove all disturbance effects (downstream of the delay time), leaving only a disturbance of the white noise type. Given any disturbance frequency, no controller can do a better job in reducing the variance of controlled variables and, in other words, an MVC controller represents the best theoretical result that can be achieved.
It is its very nature as "asymptotic maximum" that makes it an ideal benchmark for the construction of an objective measurement of the performances of a controller.

Harris' index is nothing more than the relation between the MVC control loop variance and the variance actually measured:

$$\mathbf{I} = \frac{\boldsymbol{\sigma}^2_{\mathbf{MVC}}}{\boldsymbol{\sigma}^2_{\mathbf{SP-PV}}}$$

Harris' index is therefore a number between 0 and 1: the higher the number, the higher the controller performance to the theoretical maximum. It belongs to *stochastic* [8] estimation methods, known by this name because they evaulate the response of the controllers on the basis of their statistical behaviour in the case of non-measured disturbances. It is not therefore able to provide any information on the *determinist* performances such as the response to a step variation in the set-point or disturbance, adjustment time, over-elongation, stability margin, etc.
Among its advantages must be mentioned its capacity to build an objective principle of evaluation of performances, its uniqueness (the σ^2_{MVC} value is independent of the controller structure) and its relative ease of calculation in standard industrial computers. Harris' index best expresses its potential (and is directly applicable) in the following cases:

- processes without major delay times (for instance in the case of carrying loops);
- processes describable with low-order models;
- processes where non-measurable disturbances are almost stationary

It is however necessary to recall that this is not applicable to processes with variable delay times and that an adequate compromise must be assessed from time to time between the stochastic performances and the determinist performances. To this end, it is therefore necessary that the judgment on the performances of a control loop be suitably mediated on a series of different evaluation parameters [9].

3 AN INNOVATIVE SOLUTION FOR THE INTEGRATED MANAGEMENT OF CONTROL LOOPS

In section 2 we saw how the gradual reduction of plant personnel forces the remaining technicians to take on a growing number of tasks and duties. This results in less and less time and energy being available for dedicating to monitoring process performances. To try and quantify the efforts required, we should consider that, in typical industrial situations, a control engineer has to maintain on average 4-500 loops at top performance. Considering that the analysis and tuning of a controller requires not less than 2-3 hours, it follows that keeping a control system in shape takes up between 6 and 9 months work of a highly qualified technician.
Luckily, the widespread availability of computers and of large quantities of data in real time permits automating tasks that until a few years ago would have been unachievable without extensive human intervention.

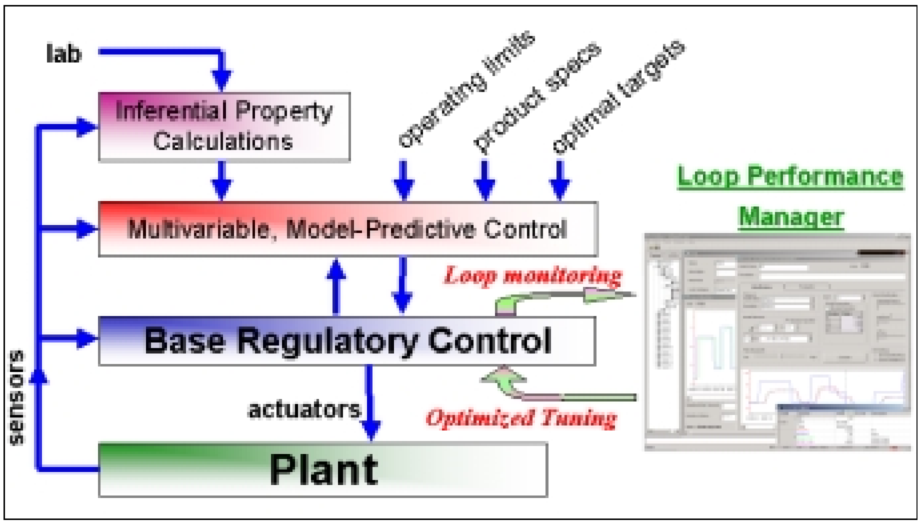


Figure 2 - Typical automatic multi-level structure

It is on the backdrop of this scenario that the authors of this memo have been engaged for some years in designing and developing new products for the application of the most recent information technology solutions in the field of automation. Such development programme, which has already produced innovative software instruments for advanced process control [10], has recently been enhanced with a solution for the optimisation and maintenance of basic tuning management.
The product, called Optimize^{IT} Loop Performance Manager (LPM) consists of a system for the systematic evaluation of the state of health of control loops (forthwith identified as *loop auditing*) and of a system for the assisted tuning of the loops themselves (*loop tuning*).
Figure 2 shows the role played by a package such as LPM in the traditional automation architecture for continuous processes. The crucial stages in the application of such a product will be briefly illustrated below.

3.1 Installation and configuration

The main raison d'etre of a product like LPM is to reduce the work load for the plant personnel. In view of this, a crucial requirement is the absolute ease of connection to the DCS and immediate use.

LPM can connect up to any control system by OPC[7] connection. Special wizards permit automatic search for the OPC Servers on the net and their guided configuration. LPM is able to connect up to a plurality of servers so as to centralise on a single platform the maintenance operations on several DCS units, including of different suppliers: a special library does in fact permit interacting with the numerous implementative variants of the PID algorithms available on the market.
To divide out the loops in an orderly way, these are grouped together and displayable according to the areas of operation to which they belong: for instance, in a refinery, it will be possible to classify the loops according to units to which they belong (crude unit, FCC, hydrocracker, utility, etc.).
The configuration of each single loop, a potentially onerous task in terms of time, tedious and most definitely prone to the introduction of trivial entering mistakes, is assisted by a Bulk Configuration utility able to import all the parameters needed from a derived Excel file, for instance, from the database of the control system itself.

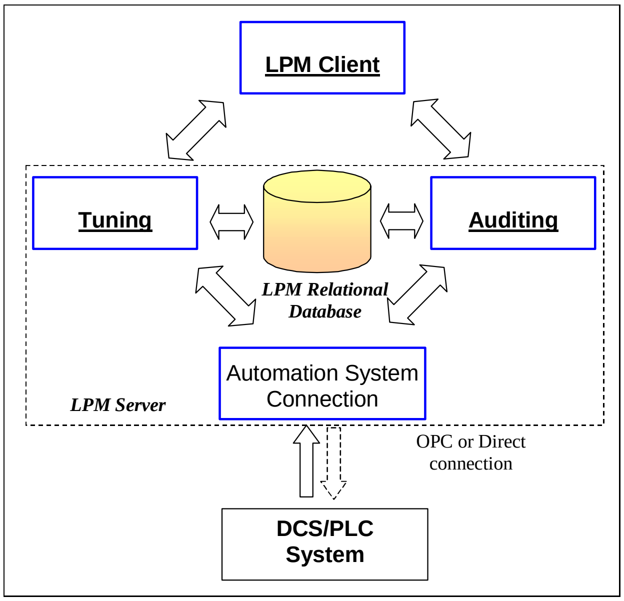


Figure 3 – LPM architecture

Special attention has been given to making the instrument intuitive and easy to use by the control room engineers. The only user interface, structured according to the most modern *Microsoft Windows®* standards, does in fact permit accessing both the auditing routines and a sophisticated environment for tuning the basic controllers, which have been pinpointed as susceptible to upgrading by auditing. Figure 3 shows a simplified diagram of the LPM software architecture.

3.2 Auditing

The fundamental requirements of an automatic performance evaluation system are:

1. **Safety**: ability to interact with the control system in an absolutely safe and non-invasive way;
2. **Autonomy**: ability to control the various stages (data collection and processing, evaluation production) in a fully automatic way;
3. **Availability**: the processed data must be stored and made available to the user at request, even after time;
4. **Interactivity**: possibility for the user to perform monitoring operations at command immediately whenever the need arises.

[7] The product is also able to connect up directly, through high-performance proprietor protocols, to some specific DCS.

LPM has been designed so that it is able to cater for this need through the following completely automated procedures:

- Collection of periodical data for the loops subject to evaluation (data "*batches*")
- Calculation of performance indices
- Filing of indices
- Performance of tests on indices to elaborate process diagnostics

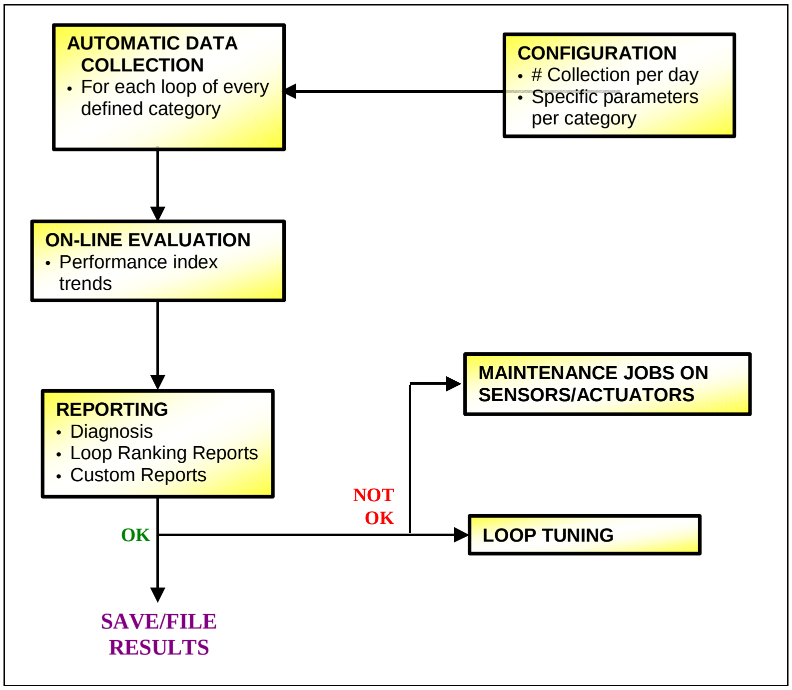


Figure 4 – Loop Auditing Flowchart

A system for evaluating tuning loop performances that intends using quality KPI such as the previously described Harris index must be able to provide a reliable value of σ value which a minimum variance controller would obtain on the single controller being examined.
This can be calculated through the use of a self-regressive model of the type shown in the following expression:

$$\hat{y}(i+b) = a_0 + a_1 y(i) + a_2 y(i-1) + a_3 y(i-2) + ... + a_m y(i-m+1)$$

As we can see, for each controller, the user should provide a series of parameters such as the number of terms to be considered in the model (*m*), the sampling interval, the extension of the data as a whole (*n*) and the prediction horizon (*b*). It is of course evident that specifying these detailed parameters for hundreds of loops would make the application of these methods impossible from a practical viewpoint [11]. The large-scale application of assessment performance methods is therefore tied to the ability to determine default values sufficiently generic for broad classes of controllers.
LPM permits grouping the controllers into categories (temperature loop, pressure loop, composition loop, etc.) each of which can be distinguished by acquisition parameters (sampling frequency, number and length of single batches, etc.) as best thought fit. According to the date configured by the user, the programme will perform the required number of data collections at set times, operating in background on several hundred loops per server. Some categories are left free (the so-called "User-

defined Categories") to permit controlling any loops which badly adapt to the default values of the major categories.
After completing data collection, the program calculates a group of *41* different performance indices and stores these in the auditing database. Of these, 3 are calculated in continuous mode (with sampling every minute for all loop types) as a statistic reference (% of time in auto mode, % of time in saturation, absolute mean error), while the remaining 38 are processed in batches, meaning at the end of each collection operation and contain all the most significant details.
Although part of the 41 indices are not directly referable to diagnostic aspects, but represent material useful for any detailed tests (for instance boolean status indices or high statistic moments), some have to be intuitively interpreted by the control room and/or maintenance staff. This is not the place to go into detail. Suffice it to say that some of the most important are:

- Harris index;
- Setpoint "Crossover" Index;
- Oscillation Indices. These include evaluations relating to the amplitude, the period and severity of the oscillation, where this is defined as the relation between the variance due to the oscillation and the overall variance of the signal.
- Operating Mode Index (auto/manual), expressed as % of the samples for which the loop was in automatic out of the total of the batch samples;
- Saturation index, expressed as % of the samples in saturation out of the total of the batch samples.

The indices remain at the disposal of the user, who can check the special time trends (Figure 5)

The reporting function generates weekly and monthly report files in *Microsoft Excel* format, that can be configured by the user. These contain information of a quantitative (the values of the calculated indices) and qualitative nature. The latter relate to diagnostic hypotheses processed on the basis of tests performed on the performance indices themselves. Examples of the provided diagnostic indices are:

- Tuning too "bland"
- Oscillation loop
- Valve not sealed
- Too much noise
- Check saturation
- Overall loop evaluation.

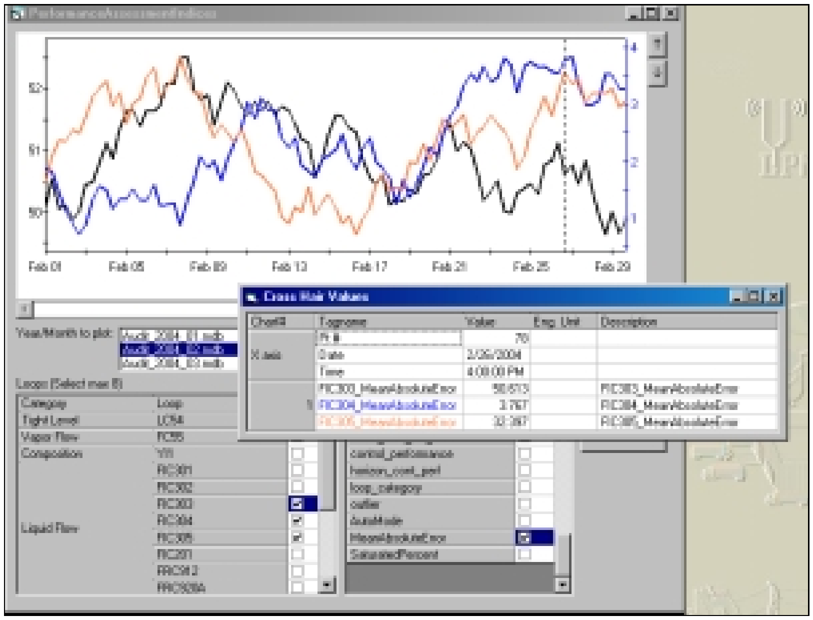


Figure 5 – Example of Trend on evaluation KPI

The user can also interact with the program at any time by configuring and asking for an additional report which will be immediately produced. The reports enable the maintenance technicians to focus on the major control problems and, when suitably stored, make possible plant performance comparisons over the long period.

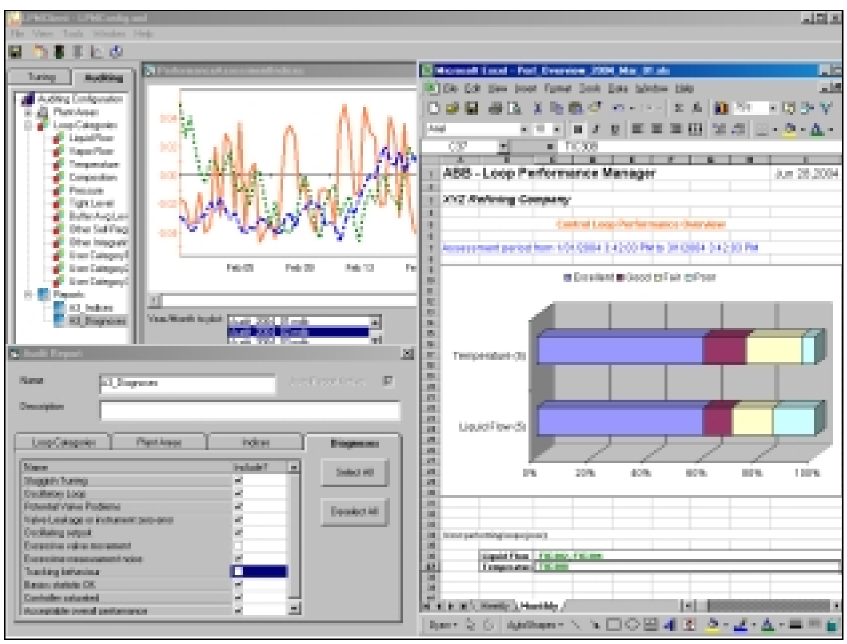


Figure 6 – Example of auditing and reporting

The auditing procedure placed at disposal by LPM is distinguished by a number of very interesting characteristics:

- Calculation of numerous indices: literature often emphasises how the detection of faults and malfunctions during control is only possible by the combined analysis of diverse indices [6];

- Conversion into a small number of clear diagnostic suggestions, the values of numerous indices often relating to statistic-operational aspects that are not uninteresting;
- Strengthening of the diagnostic results by explicit overall categorising of loops. Apart from anything else, this permits defining a hierarchy among the loops requiring attention, on the basis of their actual requirements;
- Continuity as regards monitoring on diverse time horizons. Entrusting to random samplings can easily completely falsify the evaluation of the state of health of loops operating, for instance, in very variable conditions.

3.3 Tuning

As Figure 4 shows, the auditing stage is able to detect problems or malfunctions relating both to operation of the instruments or process components, and to their control by the automation system.
While in the former case, normal inspection and maintenance is essential, in the latter it is often possible to obtain surprisingly successful results through the adequate tuning of the control loops.
For this purpose, to complete the "exploration" stage consisting of the auditing loop, LPM offers a powerful and refined utility for the assisted tuning of base controllers.

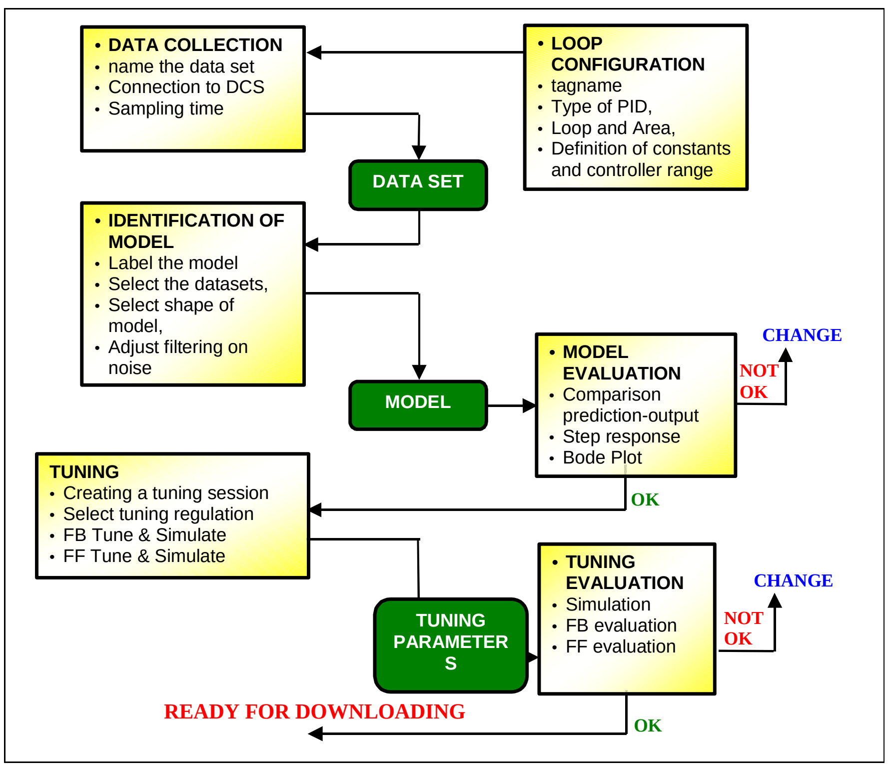


Figure 7 - Loop Tuning Flowchart

The Loop Tuning procedure occurs in the following steps (Figure 7 - Loop Tuning Flowchart):

- Collection of process data through OPC linkup or direct linkup[8]
- Processing and storing of collected data
- Parametric identification of process models
- Evaluation of models obtained
- Calculation of values of the tuning parameters of the PID

[8] Available for some automation systems

- Evaluation of the performance of the controllers with new tunings through simulations
- Filing results and tuning procedures in special *logs*.

The first step of the tuning procedure consists in data collection. In this case data collection requires an operator to prompt the process with a series of modest variations such as not to disturb normal system operation. LPM permits collecting data both with open loop (meaning with the controller in manual) and in closed loop (controller in automatic).
The robust identification algorithms at disposal permit identifying models of growing complexity including those with reverse or over-dampened response. By selecting a specific flag, models can be identified for integrator processes (level controls). The identification process occurs in separate steps: the software first of all identifies the delay time subsequently used to determine the complete transfer function. This approach adds flexibility to the system, allowing the user to manually enter previously known parameters and leaving to the software the task of finding the missing or uncertain ones. The models can be built from among:

a) Controller output and Process Variable to be used for feedback tuning;
b) Measured Disturbance and Process Variable to be used for feedforward tuning.

Great emphasis is given to the model adequacy evaluation phase: for this purpose, the user can examine both the plot (prediction vs. real data, step response, frequency response) and numerical merit factors (R^2, mean quadratic error).

Once an adequate process model has been identified, this can be used for the real tuning phase. LPM places at disposal the following tuning rules:

- lambda tuning;
- dominant pole placement for PI controllers;
- dominant pole placement for PID controllers;
- Internal Model Control for PI controllers;
- Internal Model Control for PID controllers.

In our opinion, the tuning rules at disposal offer a range of alternatives that successfully cover the various possible occurrences related to continuous process systems. The choice of tuning method is not affected by factors such as type of process model, control scenario and design criteria.

By way of example and without going into detail, we can say that generally speaking, the Internal Model Control and Lambda tuning method are preferable when the major requirement is the capacity to pursue set-point variations (e.g., in the master controller in a cascade configuration), while dominating pole positioning is more successful as regards disturbance rejection.

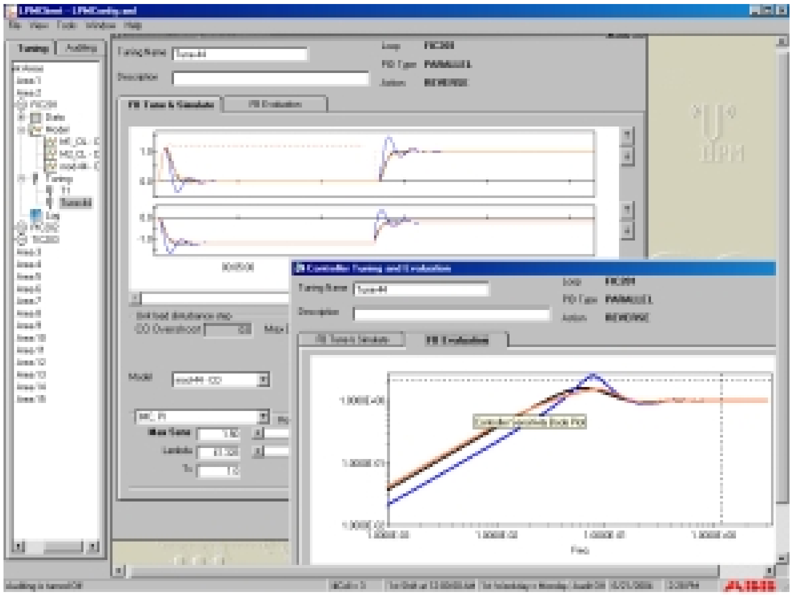
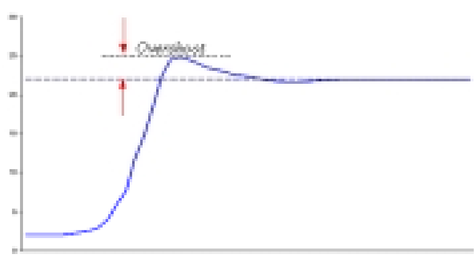


Figure 8 – Example of tuning performed with LPM

An optimisation algorithm calculates the best tuning parameters and presents simulations of the controller response both to input disturbances and setpoint variations. Plot analysis is completed by numerical indices such as the integral of absolute error, the overshoot value ([9]) or the settling time. This way the user can select the type of tuning most effective for his purposes not only on the basis of his experience or impressions deriving from a sight examination (necessarily subjective) of the simulation graphs, but also comforted by objective numerical parameters.
Finally, the user can also perform a last "*fine tuning*" adjusting the parameters by means of convenient sliders, that make it possible to comfortably explore the margins of uncertainty and stability of the controllers and find the best compromise between sturdiness and response performance.
Once the best tuning has been found for the feedback part, the user can use a similar procedure to also tune the contribution of the feedforward part, on the basis of the identified models as described in para. b) above.

Before closing the tuning activity, LPM saves the results of the session in special logs that go to form a sort of historical archive of all the jobs done on the loop. The importance should be emphasised of the "*book-keeping*" function as regards routine system operations. Storing over time details of the criteria and procedures that have resulted in the past in certain tuning parameters being selected does in fact permit protecting oneself against common risks deriving from staff turnover and eliminates the natural hesitation of younger and less expert personnel to change whatever is "in any case operating".

[9] Overshoot is the term given to the difference between the peak of the transitory response and the normal operating value of a process output (PV), with respect to a change made on the process input (CO).
A response with overshoot does not necessarily represent an intolerable behaviour; on the contrary, especially if the peak is short and not pronounced, it can be judged according to the speed the setpoint proximity is reached with this response.



Finally, it must be added how a prominent feature of the products consists of the possibility of performing tuning operations at the same time as normal monitoring functions.

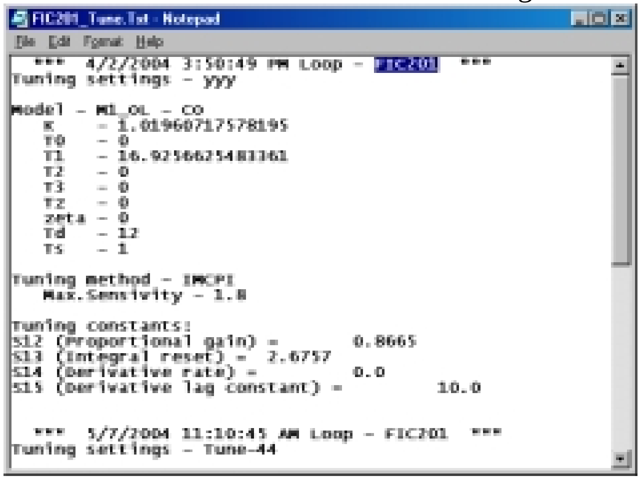


Figure 9 – Example of Tuning Log

4 EXAMPLE OF APPLICATION

One of the most interesting aspects relating to this type of technology relates to the benefits and the practical difficulties its use entails.

A first aspect to be considered is the complementarity between *tuning* and *auditing*, both in the phase of maintenance of existing systems and in the phase of commissioning new applications.
Let us take for example the case of an adjustment loop re-tuning job relating to a polymer production plant, in which the authors have taken part. In this case, the plant has been running for decades and the field instruments, as regards both the sensors and the actuators (valves, pumps, etc.), are rather old; loop tuning was first performed when the plant was started up and the relevant maintenance was done in a non-systematic way, with the practical result that some loops are well tuned and updated while others have tuning parameters dating back years and years.
In a case like this, one possible approach is to perform a *blanket* tuning of the entire loop, perhaps split up into units. This way, by analysing the loops one by one, the functionality can be checked of the field instruments and the tuning can be done. An activity of this kind would require, for the loop screening activity only, hundreds of hours of work on the part of an expert technician.
An alternative procedure would on the other hand be to configure the auditing functions and acquire data and information on the *shape status* of the various loops; this way it is easier to identify and categorise the problems of the various loops, before the tuning activity; this permits anticipating the solution to any problems and makes it possible, through the re-modulation of the activity plan, to maximise overall efficiency. An example of the obtainable benefits will be appreciated by considering maintenance of a valve affected by malfunctions, one of the most typical constraints of blanket tuning activities; by operating one loop at a time, a series of problems affecting the actuators is identified and these must be solved before going ahead with further tuning activities. By using the auditing functions, this does not occur because instrument maintenance jobs can be foreseen and anticipated, and consequently carried out *before* tuning.

Consider, for instance, the case of one of the loops retuned during the course of the project, details of which are shown in Figure 10. From a quick examination of the figure, a valve *stiction* problem immediately becomes clear, with the process variable assuming the characteristic "*levels*" shape, while the control output has a *ramp* movement. This type of problem can only be solved through actions in the field, which require a certain amount of planning and programming with the maintenance function; the possibility of an "*early warning*" therefore represents a major chance to increase efficiency in the performance of these operations.

A second aspect to be taken into consideration is the simple manner in which the tuning operations, once instrumental problems have been found and solved, can be performed; notice, for instance, that loop tuning can also be performed in closed-loop configuration, meaning by performing *steps* on the setpoint and this characteristic is much appreciated in the case of critical loops, where we wish to be certain that the process variable will never move away from the setpoint, not even during loop tuning.

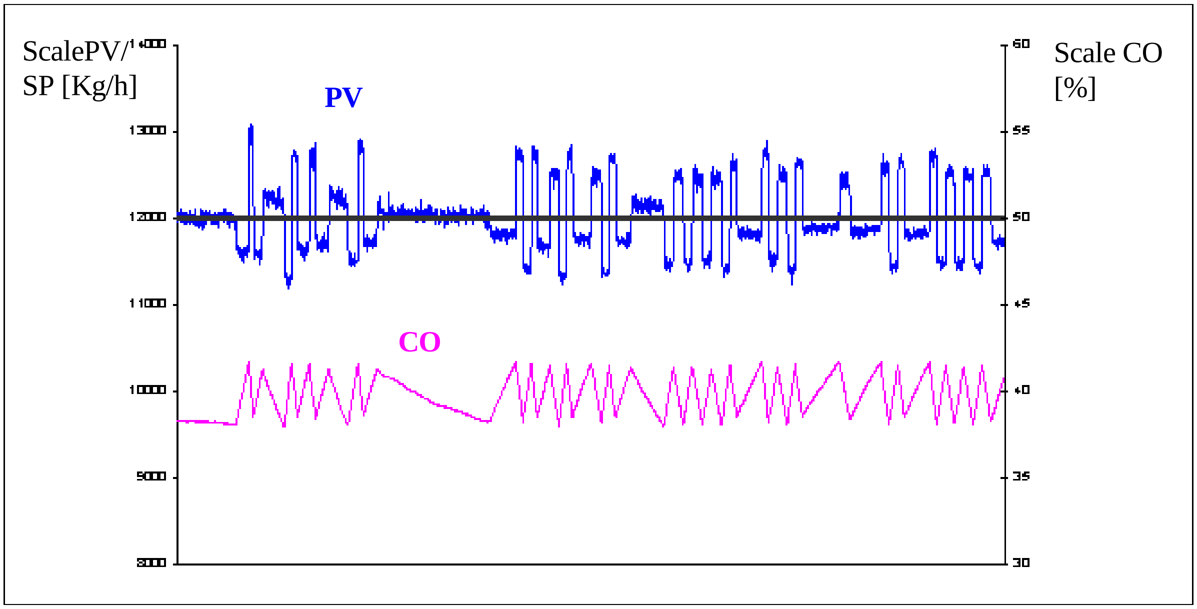


Figure 10 – Example of valve affected by stiction

Figure 11 shows an example of tuning activity performed on a plant loop; this loop is distinguished by a very quick response that can be assimilated with great accuracy at a first order (see the model shown in green in the bottom part of the figure). In the top part of the figure, the excellent loop response can be appreciated (after tuning with LPM), both as regards the rejection of the disturbance and the response to a step on the setpoint.

The results relating to tuning are provided by LPM directly in the terms of the parameters of the function code relating to the PID and can therefore be directly entered into the DCS.
Another important and useful aspect from a practical viewpoint is the possibility of exporting the log files and the reports created by LPM into other software applications. The possibility of exporting results makes the creation of activity reports and the management of tuning parameter historical databases much more simple and efficient, simplifying considerably the generation of project documentation.

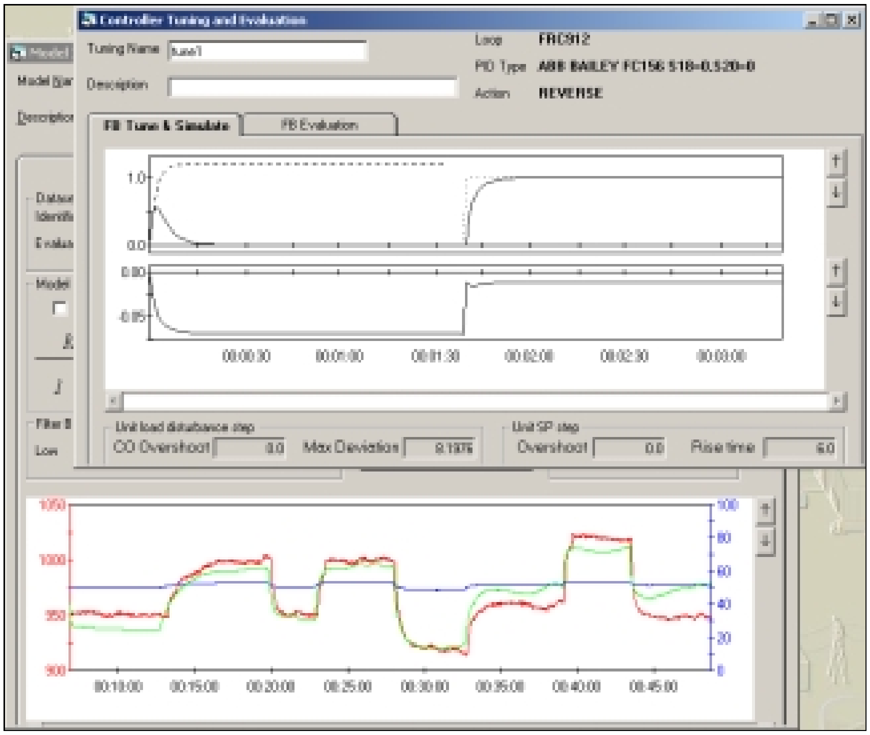


Figure 11 – Carrying loop tuning

5 CONCLUSIONS AND FUTURE PROSPECTS

The solution presented in this memo met with the interest of the market. It is based only on system data collected in standard mode. It does not require specific testing campaigns, nor any previous knowledge of process characteristics. The modern software structure gives it powerful calculation capacities and at the same time makes it easy to implement and operate, providing information in a concise and effective way.

The possibility of combining, in a single product that is easy to connect and use - as regards both the explorative part (auditing) and the executive part (tuning) - together with the reliability of the responses, makes it one of the most interesting platforms for conveying, in the process industry, the results which research has produced in the field of basic tuning management.

Encouraged by the confirmations received from end users, the work team is working to extend the above-described functionalities according to a development plan that moves in three main directions:

1. upgrading of basic information technology structures with gradual extension of connection and reporting capacities (remote access, formats compatible with multimedia requirements, showing the indices that have undergone significant variations between reports relating to two different periods);
2. introduction of concepts and research methods relating to the root causes of disturbances;
3. gradual inclusion of process performance evaluation.

While the first point concentrates essentially on the creation of a series of functions that make the information produced by the existing package even more easy to use, points 2 and 3 deserve a few words more.

Once it has been ascertained that a process is no longer operating as expected, the important thing is to be able to determine the root cause of the deviation from expected behaviour. The search for methods able to pinpoint the root cause (*root cause analysis*) has witnessed the expenditure of a great deal of effort over recent years (for more details see for example [12]) and has led to the finding of methods and instruments which promise to be very interesting for the process industry.

Control system evaluation methods can provide useful indications not only as regards the state of the controllers themselves but also of the components with which these interact. They can for instance underline the suspicion of the presence of leaks or malfunctions of sensors and actuators. The completion of such information with an overall evaluation of the state of the process and of its single hardware components naturally represents the ultimate aim of any monitoring system. The inclusion of powerful statistical methodologies within commercially available products [8], opens up the possibility of realising integrated systems that can cater for all the requirements of a modern plant.

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