Control Performance Monitoring: Bridging the gap between the industry and academics

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Abstract
Control Performance Monitoring has been getting a lot of emphasis in both the industry and academia especially since after Model Predictive controllers became commonplace. Many techniques proposed in academics for monitoring the performance of automatic controllers. However, these techniques have failed to gain traction in the industry and the need for simple and useful metrics for monitoring control performance remains unfulfilled in industry. This paper aims to explain the reasons for the gap between the academia and industry. Means of addressing the gaps are suggested. Observations from the industry are based on the authors own experience.

Keywords: Control Performance Monitoring, Model Predictive Control, Control Performance Assessment

1. Introduction
Over the past decade the oil, gas and chemical manufacturing industries have invested heavily in the advanced process control applications, the most common of these being model predictive controllers. Interest in assessing the performance of these controllers has also been growing due to the recognition of these controllers as important assets that have to be monitored and maintained.

The importance of monitoring control performance in the chemical industry has been widely recognised. The term monitoring means the action of watching out for changes in a statistic that reflects the control performance over time [1]. Accordingly, in this paper, controller monitoring shall mean controller performance monitoring (i.e., excludes diagnostics). With the wide spread
use of Model Predictive Controllers in the industry, the need for good tools to monitor their performance is recognized in both the industry and academia. Figure 1 illustrates the questions that a control performance measurement and diagnosis strategy seeks to answer ([1]).

![Diagram of control system](image)

Figure 1: Simplistic statement of control performance assessment [1]

Various methods have been suggested in the literature for monitoring the performance of these controllers. Commercial products have also been developed for control performance monitoring [2] Many of these products are based on academic research. In the industry however, these methods have not proved very successful. It has been reported that over 60% of controllers in the industry do not perform satisfactorily [9]. No single uniform method exists for monitoring control performance in the industry, even for similar applications. This is surprising given that the importance of control monitoring is well recognized in both the academics and the industry.
This paper tries to analyze the reasons for this situation and bridge the gap between the academic and industrial world. The approach taken by the academia is first studied and the reasons for their not being well accepted are discussed. An attempt is made to identify the needs of the industry and how these needs can be addressed.

2. About the author

The various observations about the industry mostly stem from the personal experiences of the author. The author has over 15 years of experience in the chemical process industry across a variety of sectors including paints, energy and mining. Most of the experience is in the process control and advanced process control areas, initially as the end user working in a top Fortune 500 company and subsequently as a vendor and consultant working on implementing control performance monitoring projects for customers. The author has experience in monitoring both model predictive control and regulatory control loops.

The author has been involved in working on various control projects from concept to design and commissioning. He has worked with all levels of management on these projects, from operators to senior management. He has an understanding of the requirements of the multiple stakeholders in a large project such as an MPC, and the constraints and expectations of these stakeholders.

The author has also experienced firsthand the challenge of control performance monitoring and the difficulties faced by the industry. He has worked on the business development, installation, commissioning, training and customer support for control performance monitoring products. Having worked closely with many customers from different sectors of the industry, he is able to appreciate their viewpoint and understand their difficulties with the solutions currently available in the market.

It is hoped that this paper will help bring the academic and industrial viewpoints together so that a meaningful solutions to control performance monitoring can be developed that will be a good fit to industrial requirements.
3. Academic approach

Often academia makes an attempt to capture control diagnostics (or fault assessment) into a control performance metric. This is not a good approach, as will be explained subsequently. In this section, we will only consider control performance monitoring methods proposed in the literature, and not diagnostics.

An excellent review of control performance monitoring has been presented by Jelali [1]. From this review, we can see that the various approaches taken by academia in the area of control monitoring can be divided into 2 broad categories.

In the first approach, the performance of a controller is compared against theoretical bounds such as the Minimum Variance Controller Benchmark ([7], [1] and [10]) and its variations or other benchmarks such as the LQG benchmark ([1],[2],[6]).

This approach has 2 drawbacks. Firstly, the industry seldom requires its control performance to be close to theoretical limits. This makes such comparisons irrelevant. Indeed, from an industrial point of view, acceptable control is far more important than best possible control (see figure 1) [8]. For example, if a product run takes 24 hours for completion, it simply does not matter if the rise time for the product flow is 4 minutes or 5 minutes. Most process operators are unable to specify performance benchmarks in terms of rise times or settling times – any figure that is very small compared to the length of the run (or the shift) is good enough.
Figure 1: Aggressive Control (top) vs Acceptable Control (bottom). While the performance of the control loop at the top (settling time = 1 min) is close to the theoretical best, the one at the bottom (settling time = 2 min) is equally acceptable.

Another limitation of this approach is that this metric requires to user to have a good understanding of the theory being used for the design of the metric. Given that these metrics are theoretical requiring a fairly deep insight into the mathematics of a control loop, it is not surprising that these metrics are difficult to explain to and be understood by a typical plant engineer, leave alone an operator. It is the author’s personal experience that these metrics are often not easily grasped even by people holding doctorate degrees. Given this difficulty, it is not surprising that these metrics are quickly rejected by the industry.

Apart from these, minimum variance control benchmarks require estimates of the dead times, these are often not readily available. Wrong estimates of these render the benchmarks useless.

The second approach taken by the industry is to compare the performance of a controller against a “Golden” period of operation where the controller performance was supposedly at its “best”
Various methods (often statistical) can then be used to compare the performance of the controller against the benchmarked data. The issue then comes down to finding such a golden period, which, except for the simplest of systems, is hard to come up with. For a large plant, it is very unlikely to have all the CVs and MVs performing at their best at any point in time.

Another issue with control performance monitoring methods in the literature is that there is no single accepted method for linking the performance of the controller to the economic benefits. Many control projects, especially Model Predictive Controller projects, are initiated with a view of obtaining returns on investment. Such projects involve a fair amount of investment in terms of time and effort of personnel, often including specialists and procurement of software, hardware and network components. A means of quantifying the economic benefits of the project is an essential requirement in the industry.

With the drawbacks of these current methods, it would be expected that there would be many issues with controllers in the industry. Indeed, It has been reported that as many as 60% of all industrial controllers have performance problems [9].

4. Stakeholders

As discussed in the previous section, the metrics proposed by academia expect the user to have sufficient theoretical expertise in understanding the working of the metrics. Such expertise can only be expected from the engineering team. This means that the metrics proposed by the academics do not consider the other major stakeholders in the plant. In this section, we will identify the major stakeholders and understand their roles, responsibilities and expectations from performance metrics. Note that we are only looking at a controller that is commissioned because the performance metrics will only apply to a running controller.

The first major stakeholder is the operations management. The operations team is responsible for the safe and profitable operation of the plant. The operations team owns the controllers. A control system project requires commitment and buy-in from the operations management and the management expects the project to deliver an economic benefit. This team is primarily interested in an economic performance measure for the controllers.
The next stakeholder is the process operator. The process operator is primarily responsible for safe operation of the plant and to ensure that the production targets are met. Needless to add, buy-in from the process operator is critical to the success of any controller. The operator is responsible for running the plant safely and will choose to turn off the controller if he or she does not feel comfortable that the controller cannot keep the plant stable or if it cannot be used to meet the plant targets. Issues of controllers being turned off or MVs severely clamped can be seen in almost all case studies of Model Predictive Controller performance in the industry. The operator expects the controller to help meet the process targets. A metric capturing the target information is relevant to this stakeholder.

The next stakeholder is the control engineer. Often, a dedicated engineer is designated on completion of a major control system project (such as implementation of Model Predictive controllers) to maintain the controller. This engineer is a custodian of the control and is responsible for ensuring that the control is online and used in the best possible manner. He or she works with the operator to ensure that operators do not have difficulties in using the controller and that it is tuned. The engineer in charge of a model predictive controller is also expected to “tweak” the plant model and retest the plant whenever there are changes to the process. The control engineer is interested in controller diagnosis but has to ensure that the performance expectations of both the process operator and the operation management are met.

5. Controller Monitoring and Assessment Reporting

Keeping in view the requirements of the various stakeholders, it is recommended that a control Monitoring and Performance Report should have the following information:

1. **Controller Utilisation:** This is the amount of time that the controller is used by the operator effectively. Effective use means that the controller must have sufficient degrees of freedom available to control the process.

2. **Control Performance:** The control performance metric should be meaningful and readily understood by all stakeholders. It should also be possible to work out the metric using routine plant operational data. One of the simplest metrics that can fulfil these requirements is the control objective itself. The error and standard deviation of the control variables from their steady target targets over the long term provide a simple and
meaningful measure of the effectiveness of the controller. In addition, this has the benefit of being directly correlated with the plant economics.

Note that other than, the utilization and performance measures are independent of the underlying control algorithm and therefore, can be applied to any control application, including PID control and multivariable regulatory control. These metrics, can therefore, also serve as a comparison between benefits from different control strategies.

Figure 3 shows how these different metrics can be used for ensuring that the control performance is kept optimal.

![Flowchart showing the control performance monitoring and diagnosis workflow.](image)

Figure 3: Control performance monitoring and diagnosis workflow
6. Conclusions

Academic researchers have developed a keen interest in monitoring the performance of control applications in general, and model predictive control applications in particular. This effort has resulted in a plethora of publications as well as commercial products aimed at monitoring the condition of controllers. However, most of these techniques have gained widespread usage in the industry and the need for good control performance measurement tools remains unfulfilled. This paper analyses the causes for this, based on the author’s own experience in the industry. It lists the deficiencies of the current approaches in an industrial environment. The proposed metrics have to be relevant to all stakeholders in the industry, hence it is important to understand who these stakeholders are and their expectations from control performance. In this paper, the use of long term control objectives has been suggested as control performance metrics, which meets the requirements of the various stakeholders in the industry.

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