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# Automated Control Performance Monitoring and Automated Tuning with Alarm-Based Adjustments

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**Abstract:** Traditional PI/PID tuning methods often rely on trial and error or require time-consuming open-loop step tests, which disrupt routine closed-loop feedback control. Traditional retuning procedures typically don't take a holistic view including bounds settings or process restrictions and therefore fall short of substantial improvements of the controller performance. The Controller Performance Monitoring (CPM) methodology addresses these challenges through automating and data-driving the process. It encompasses data collection, quality checks, benchmark estimation, KPI calculation, and control chart monitoring. A Key Performance Indicator (KPI) is used to quantify the performance of the control system, with deviations indicating when retuning is necessary. Alarms are triggered when KPI thresholds are breached, prompting retuning recommendations. CPM continuously tracks system performance, updating suggestions in real-time and offering a user-friendly interface for informed decision-making, ensuring that retuning efforts are only applied when truly beneficial.
**Keywords**: Key Performance Indicator; Control Chart Monitoring; PI/PID Controllers Tuning; Alarm Rule System

## CPM Methodology

CPM is an automated, data-driven methodology aimed at enhancing the performance of process control systems, particularly PI/PID controllers, [1]. By leveraging operational data, CPM identifies when and how to retune controllers without the need for time-consuming tests. It compares current controller performance against a benchmark model derived from historical and operational data, allowing for efficient performance monitoring and retuning recommendations. The model tracks performance degradation through a KPI and uses control charts for alarms to trigger retuning, when necessary, thus avoiding unnecessary interventions. Key steps in the CPM are as follows:

1. To ensure accurate analysis, synchronized windows of data are collected for the Controlled Variable (CV), Manipulated Variable (MV), and Setpoint (SP). The data must maintain consistent resolution and precise time alignment, enabling reliable comparison and interpretation.

2. Data quality checks are conducted to ensure its suitability for subsequent analysis and controller performance evaluation. This process addresses three critical aspects: usability for benchmark modelling as poor-quality data can result in numerical instabilities and inaccuracies; operational insights gained through data analysis, which can reveal operational issues such as MVs reaching their bounds thus requiring maintenance or adjustments beyond simple retuning of control parameters; and controller mode verification ensuring the data comes from an automated control mode.

3. Data pre-processing involves filtering the data (CV, MV and SP) to remove high-frequency variations and noise, ensuring a smoother signal is used for benchmark modelling enhancing the accuracy and reliability of the estimation process.

4. Benchmark estimation is conducted only after ensuring that all collected data, including MVs, CVs, and SPs, meet the required quality standards. This process involves: the benchmark model, developed using data from routine closed-loop feedback control; and the benchmark controller,

designed based on the model. This method ensures the benchmark reflects realistic and achievable performance, contrasting with idealized controllers, such as minimum variance controllers, which may not be practical in real-world scenarios.

5. The calculated KPI is used to quantify the alignment between the current control system performance and the benchmark. A KPI value approaching one signifies performance close to the benchmark, while deviations from one indicate potential areas for improvement (e.g. the need for retuning the controller). Since the KPI is a relative metric, it can be compared to fixed control chart limits. This removes the necessity for regular updates to the limits, providing a stable and efficient framework for assessment.

6. The KPI is plotted and monitored on a control chart that incorporates alarm and warning limits. The alarm limits represent critical thresholds, signalling the need for immediate retuning of the controller to prevent performance degradation. The warning limits indicate issues that may require retuning in the future. This dual-limit approach prioritizes control actions and ensures timely intervention when necessary.

7. The alarm system offers adjustable sensitivity, enabling users to configure the number of times the KPI must breach a rule before triggering an alarm. This flexibility ensures that alarm thresholds are tailored to the user's preferences and the specific dynamics of the system. When the KPI surpasses the configured threshold for alarm violations, the system generates an alert, notifying the user and recommending retuning actions to address the issue.

8. When a retuning alarm is triggered, the method provides recommendations for retuning the PI/PID controller parameters based on the current operational performance and the benchmark model.

9. The method continuously monitors the KPI and updates retuning suggestions as necessary, ensuring control performance is updated.

10. An interface can be added to allow the user to view the results of the CPM process, including the KPI, benchmark comparison, and retuning suggestions. This provides a transparent, user-friendly way to track performance and make informed decisions regarding retuning actions.

**Restoring Process Performance: Alarm-Triggered Controller Tuning with CPM**

Figure 1.1 demonstrates how different rules can be activated at various times, showcasing the CPM algorithm's ability to automatically monitor and adjust process performance. Our alarm system is designed based on established statistical process control principles, [2], [3], [4], [5]. For example, alarm rules trigger when the KPI breaches limits (red dashed lines) for consecutive instances, avoiding unnecessary responses to temporary deviations.

Initially, slow controller tuning leads to poor performance, causing the KPI to breach the upper alarm limit multiple times (top-left graph). After four consecutive breaches, Rule 1 is triggered (second-left graph), prompting CPM to adjust the tunings ($K_c$ and $\tau_i$) improving performance and keeping the KPI within limits.

Between samples 40–60, a disturbance changes process dynamics, making the previous tunings too aggressive and causing the KPI to breach the lower alarm limit for four consecutive instances

(top-left graph). This activates Rule 6 (second-left graph), and CPM adapts the tunings again, restoring performance.

This example demonstrates CPM's adaptability in handling slow and aggressive control behavior. The algorithm supports additional rules for monitoring deviations, trends, and warning breaches (yellow dashed lines), providing a flexible strategy to maintain process performance.

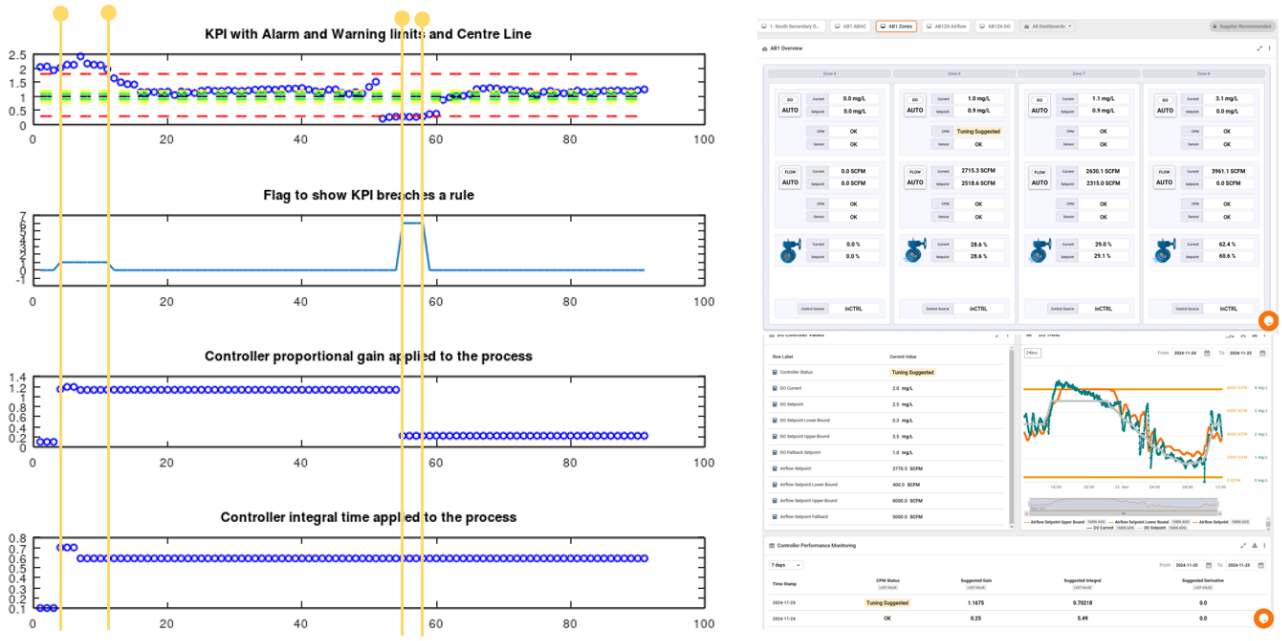


**Figure 1.1** Visualization of KPI Monitoring, Rule Violations, and Automated Controller Tuning Adjustments

The CPM methodology serves as the core functionality for assessing and improving control system performance. Dashboards (right images) provide real-time visualization of CPM results, enabling operators to monitor control performance continuously. By displaying key metrics such as controller status, setpoints, and control trends, dashboards help users track deviations, evaluate performance, and receive tuning recommendations when necessary. Whether implemented locally or on the cloud, dashboards enhance CPM by offering an intuitive interface for real-time decision-making.

## Conclusion

The CPM methodology provides an efficient, data-driven solution for automated assessment and improvement of control system performance. By automating data collection, quality checks, benchmark estimation, and KPI calculation, CPM ensures that control systems are tuned based on actual performance rather than relying on trial-and-error or disruptive testing. The system triggers alarms and provides retuning recommendations when necessary, improving performance while avoiding unnecessary interventions.

**References**

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