Estimation of controller benefits: an optimization-based approach

BY Y. ZHOU, J. BAO, P.J. MCELLELLAN AND J.F. FORBES

Perhaps, the most comprehensive treatment of control systems benefits analysis process currently available is Marlin et al. [1]. The core of the procedure outlined by these authors is: 1) the definition of a base case process operation often in terms of process variability; 2) the identification of performance improvement opportunities, usually in terms of process variability reduction; and 3) the valuation of performance improvements that may arise due to any proposed control system upgrades. Although, Marlin et al. [1] provide the complete benefits analysis framework, they discuss only the most common approach to estimating the economic benefits that may accrue from improving the control system. The core of any benefits analysis procedure must be an accurate method to estimate the potential benefits of a proposed control system improvement, since the economic justification for these improvements and the resulting business decisions are based almost entirely upon such estimates. High-performance control systems are often considered part of the competitive advantage of many companies. Thus, accurate estimation of the performance benefits that will accrue from a process-automation system improvement (e.g., upgrading or replacing existing control systems, adding sensors, and so forth) is a crucial component in improving the value of process operation in today's business environment.

Figure 1 illustrates the conventional approach to benefits estimation. Improved control results in a reduction in variance of the controlled product quality. For an automation system improvement, the setpoint for the desired product quality can be moved closer to the quality specification, while ensuring some allowable violation rate for the specification. The difference (Δ) between the existing setpoint and that used after an automation system improvement usually relates directly to an economic benefit (e.g., an increase in process throughput, a material and/or energy savings, and so forth). Latour [2] makes the point that a more "natural" way to view the economic performance of an automation system is in terms of the trade-off between the economic incentives for pushing the process toward the product quality specifications and the costs associated with violation of these specifications. This is accomplished via an economic model of the "trade-off." In Latour's approach, the probability density function (PDF) for the key process variables is determined either directly from the process operating data or is estimated. Given the PDF for the process variables and a function that expresses the cost of deviation from the specification (for deviations that are within specification and those that violate them), an average operating point can be determined that best reflects the economic trade-offs with the process variation. Thus, this operating point depends not just on process variance, but also on market conditions.

Both the conventional and Latour's approach to benefits analysis have difficulty in dealing with complex, multivariable processes where it is not clear which of the many operating constraints need to be "pushed." This paper proposes a systematic approach to determining the benefit that will accrue from a proposed automation system change, which poses the benefits determination problem in Stochastic Optimization form. This formulation properly reflects the multivariate nature of the benefit estimation problem. Further, the benefits estimation stage is performed in a very similar manner to the Analysis of Variance (ANOVA) calculation for the statistical comparison of two different treatments. Thus, this proposed benefits decomposition approach allows the proper attribution of economic performance improvement, which should result in more reliable decision-making.

**BENEFITS ESTIMATION**

The method proposed in this paper is a fusion of the work of Marlin et al. [1], Latour [2] and Kookos and Perkins [3], with the addition of steps to determine the "best" achievable performance of control system configuration using current optimization methods, into a six-step procedure. The core technology, on which the proposed approach is based, combines the CLIFFTENT idea proposed by Latour [2] with the recognition that the operating point should be determined via the solution of an optimization problem. Problem (1) states the benefits determination problem:

\[
\min \mathbb{E}[C] = \int \phi(y, s^*) \cdot f(y, \tilde{y}, Q, ...) \, dy
\]

subject to:

\[P(h(y) \geq s^*) \leq \alpha] \]

where: \(C \) is the cost of the operation; \(E \) is the expectation operator; \(f \) is the probability density function for the process variables; \(h \) is a vector

Y. ZHOU
University of Alberta, Edmonton, AB

J. BAO
University of New South Wales, Sydney, NSW, Australia

P.J. MCELLELLAN
Queen's University, Kingston, ON

J.F. FORBES
University of Alberta
Edmonton, AB
fraser.forbes@ualberta.ca

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