Journal of Process Control 38 (2016) 1–10

Contents lists available at ScienceDirect

Journal of Process Control

journal homepage: www.elsevier.com/locate/jprocont

Review

The current state of control loop performance monitoring – A survey of application in industry

Margret Bauer[a], Alexander Horch[a,*], Lei Xie[b], Mohieddine Jelali[c], Nina Thornhill[d]

[a] ABB Corporate Research, Wallstadter Str. 59, 68526 Ladenburg, Germany
[b] Institute of Cyber Physical System Engineering, Zhejiang University, Hangzhou, China
[c] University of Applied Science Cologne, Betzdorfer Str. 2, 50679 Köln, Germany
[d] Centre for Process Systems Engineering, Imperial College London, South Kensington Campus, London SW7 2AZ, UK

ARTICLE INFO

Article history:
Received 6 March 2015
Received in revised form 6 November 2015
Accepted 7 November 2015
Available online 24 December 2015

Keywords:
Control loop performance
Industrial process
Monitoring
Fault detection
Process control
Survey

ABSTRACT

Control loop performance monitoring (CPM) in industrial production processes is an established area of research for which many methods to detect malfunctioning loops have been developed. However, it is unclear which methods are successful in an industrial environment. Often, there are additional aspects such as organizational issues, data availability and access that can compromise the use of CPM. In this paper, we are reporting on the results of a survey amongst CPM users. The survey takes stock of existing methods and their use in industry as well as which faults are most frequent and can be detected. Organizational as well as implementation issues are investigated and discussed. This paper aims to identify open research topics and the direction of development of CPM in industrial production processes.

Contents

1. Introduction

Plants in the process industries use predominantly PID controllers to keep important process variables at their desired setpoints. The concept of PID control was introduced to industrial production processes in the 1930s to 1950s [1], first on a small scale with a few pneumatic loops per process and today on a large scale

* Corresponding author. Tel.: +49 6203 716463.
E-mail addresses: margret.bauer@de.abb.com (M. Bauer), alexander.horch@de.abb.com (A. Horch), leix@csc.zju.edu.cn (L. Xie), Mohieddine.jelali@fh-koeln.de (M. Jelali), n.thornhill@imperial.ac.uk (N. Thornhill).

http://dx.doi.org/10.1016/j.jprocont.2015.11.002
0959-1524/

with several hundreds if not thousands of PID control loops digitally implemented.

With the advance of automatic control came the need to assess the performance of the control loops, according to the business stratagem "If you can't measure it you can't manage it." Increasing computational power enabled assessments which looked, for example, at the standard deviation of process trends. Standard deviation or variance is an obvious candidate as a performance index because many engineers selling control solutions use a depiction of data "before" control improvement and "after" where the "before" case shows a heavily fluctuating process variable and the "after" a near constant smoothened out time trend.

A key challenge in the assessment of control loops is to distinguish between a controller that was performing poorly (A) because there was something wrong with it and (B) because of an outside disturbance. This was first addressed by Harris in 1989 when he published "Assessment of closed loop performance" [2]. The measure, later to be named the "Harris index" compares the variance of a process variable to the minimum achievable variance, which is caused by outside disturbances. This paper attracted a significant amount of interest in the academic world of control engineering and brought the problem formulation closer to research institutions.

A reason for the focused attention on the assessment of control loops was that despite the prevalence of PID controllers ensuing studies found that the controllers were not doing as well as everyone had assumed [3]. In fact, before a measure was introduced, controllers were just used. Now these controllers were "good" or "bad", "acceptable" or "poorly performing". And most studies found that there more "poor performers" than expected.

A key requirement for the assessment of control loops is that data from routine operation and closed loop control should be used. The initial assessment of a single control loop has since then expanded to frameworks and procedures, and includes diagnosis, fault identification, isolation, and root cause and plant wide disturbance analysis. This research area today is often called control loop performance monitoring (CPM).

CPM now forms a substantial body of research articles and industry applications. Over the 25 years since the publication of the original article, several review articles and tutorials have been published. The first reviews were written about a decade later [4,5] focusing the multivariate extensions, feedforward control and industrial aspects. Hägglund [6] as well as Jelali [7] made significant contributions by explaining working indices in plain terms and providing codes for industrial implementation. More recently, the Springer series "Advances in Industrial Control" includes four monographs on control performance assessment, including valve stiction detection [8–11]. Furthermore, the recent textbook [12] explains established methods in detail and gives frameworks, implementation guidelines, applications and tools.

CPM was developed in close cooperation with industry. In [7], a list of research articles and their industrial applications in the chemical, petrochemical, pulp and paper and other industries in provided. The same article also lists the commercial packets that comprise control loop monitoring tools, either as stand-alone solutions or built into automation and control software.

In this article, we are scrutinizing what has been achieved in industry in the last three decades. The focus is on the production companies in the chemical, oil and gas, pulp and paper and other industries that use CPM to manage and assess the control of their processes. The questions addressed here are:

- What works in industry? Which methods are most useful? Which frameworks and processes are successful?
- Is CPM a standard or only used by leading production companies?
- What are the key challenges? What are the open research topics?

These questions were gathered into an online survey that was distributed to control engineers at production plants in various industries and around the world. Since a survey requires a comparatively large number of participants we have focused the content on single control loops and particularly on PID loops.

The results of this survey amongst CPM practitioners are presented in this article. The methodology of the survey and the background information of the survey respondents are described in Section 2. Section 3 discusses the awareness of CPM and the scope: how well are control loops performing today? Is there still a need for CPM? In Section 4, the prevalence of the various methods as well as problems that can be addressed by CPM are discussed while Section 5 investigates procedures, frameworks and workflow that further the success of CPM in industry. Section 6 looks at future research directions and the satisfaction of CPM users with current tools and methods.

2. Survey description

An online survey was conducted to capture the prevalence of CPM worldwide. There is an abundance of publications on survey methodologies for all survey purposes and groups of respondents [13]. Many providers offer free platforms to easily format questionnaires and capture results. For this survey, the authors chose Google forms, which is part of Google drive and does not require any software installation. In addition, the results are stored in spreadsheet form and reports are generated automatically.

The design of the questionnaire is the most important aspect of the survey. When putting the questions together many pitfalls have to be avoided. For example, the questions have to be phrased objectively and clearly in a coherent order. Non-exhaustive listings must be avoided. To ensure a high response rate, the questions must be meaningful and interesting [14].

To ensure the validity of the questions, interviews with industry experts were conducted and the survey questions were discussed. These experts were Florian Wolff at BASF, Germany, Duane Muller at AngloAmerican, South Africa.

For this type of survey the group of respondents are limited. The respondents were identified as lead control engineers in production companies from various industries. In order to address the target audience, several approaches were started. First, all personal contacts of the authors were approached. Second, what is referred to as 'snowball sampling' was pursued, that is, known responding control experts were asked for referrals among their colleagues. Thirdly, published authors in the area of CPM that now work in industry were approached. The contact data was retrieved from the journal article or conference proceedings. In addition, the survey was distributed in a Honeywell user group meeting and the participants filled the results in during the meeting. All responses, electronic or on paper, were anonymous.

In total, 69 control engineering experts in production companies answered the survey. Fig. 1 lists the respondents by continent and by industry. Roughly half the respondents were from Europe (33 out of 69) because the authors' contact were used to send out the questionnaire. The majority of respondents (64%) work in chemicals or oil & gas. This may be partly explained because chemical and petrochemical companies are traditional strongholds of CPM. It should be noted that the answers do not always add up 69 because not all respondents answered all questions.

The respondents have various levels of experience in control engineering, as indicated in Fig. 2. The total is about 1000 years of control engineering experience on which the survey is based on.

Respondents were also asked how many loops are allocated for each control expert and the results are displayed in Fig. 3. On average, a control engineer is responsible for about 450 loops. However,