Process control performance is a cornerstone of operational excellence in the refining, petrochemicals, pulp and paper and the mineral processing industry. Control performance assessment and monitoring applications have become mainstream in these industries and are changing the maintenance methodology surrounding control assets from predictive to condition based. Honeywell Hi-Spec Solutions published a detailed industrial survey in 2001 which explained why the technology is so necessary in the process industries: it is because every control loop is different, in contrast to examples like the position control of the head in a computer hard disk drive where one optimised design can be reused in every unit.

The large numbers of control assets in most sites compared to the number of maintenance and control personnel has made monitoring and diagnosing control problems challenging. Nevertheless, continuous improvement in process performance must be ensured by constantly monitoring and assessing the performance of the basic control loops, and diagnosing the sources of problems.

New directions in control loop assessment and diagnosis

by Nina F. Thornhill and Sirish L. Shah
The ARC Advisory Group has emphasised the importance of controller performance monitoring, characterising it as a “crucial technology underpinning optimisation of capital intensive operations with slim margins in which continuous processing with infrequent product changeovers is the norm”. With this in mind, a group of industrial end users, technology vendors and academics met at the IEE Seminar on Control Loop Assessment and Diagnosis (CLAD) on 16th June 2005 in London to explore the state-of-the-art and to consider new directions.
of poor performance whether it is from poor tuning, sticking valves, disturbances entering from outside the loop, or some other root cause.

CONTROLLER PERFORMANCE ASSESSMENT

The basic idea of process control is often characterised as diverting process variability from variables where we can ill-afford large variations to variables (e.g. manipulative actions) and/or buffer tanks that have room. The overall aim of a controller performance assessment application is to check that this is being achieved. Running of such an application requires:

- Collection of suitable data for analysis;
- Benchmarking the performance of each controller against a suitable standard; and
- Presenting advice and reports that the plant control engineer can use to improve control to meet business objectives such as maximising throughput or reducing energy consumption.

Data collection from a plant historian has been greatly aided by the development of the OPC open standard, and assessment of the controller performance against a minimum variance or a user-defined benchmark is also relatively straightforward. The current focus is on the third requirement, of how to give relevant and useful information that relates to business objectives.

We hope you will enjoy the three following articles in this special section of Computing & Control Engineering which highlight several aspects of this important industrial technology.

All the presentations from the Seminar can be viewed at the seminar web site www.iee.org/oncomms/pn/controlauto/CLAD_Papers_2005.cfm where they will be posted until the end of September 2005. (After September 2005 the articles will still be available through the online library; readers should do a search for “control loop”.)

The following text gives a brief overview of the topics discussed at the event.

THE TECHNOLOGY

There has been a need for some time for control loop performance assessment to focus on control loops which are economically critical and so prioritise monitoring these loops in a ranked order. A talk from Honeywell Hi-Spec Solutions (Andy Trenchard and Howard Boder) described how control loop performance assessments are being turned into controller maintenance priorities. The priority depends on the extent of performance degradation and the control loop criticality. The talk gave examples and a checklist to help decide the importance of a controller and to aid the determination of its criticality. One example of a critical loop is one whose manipulated variable causes an unmeasured disturbance on other control loops. The maintenance of critical loops with poor performance is a high priority because it represents a large opportunity to make the whole process run better.

Professor Sirish Shah of the University of Alberta with co-authors from the university and Matrikon described the ideas behind control loop performance assessment and diagnosis. A take-home message is that detection of poorly performing controllers is straightforward while diagnosis is more challenging and may need a variety of methods including spectral analysis and higher-order statistics for detection of process non-linearities such as valve stiction.

Presentation of meaningful advice and reports is also a challenge in a large process which may have hundreds of control loops. The problem is having enough wall space...
to show both the overview of a process and the detail of every control loop in each unit within the process. The talk presented a method for visualisation of the control loop performance status of a large process using a tree map which shows the whole process and draws attention to areas needing attention by use of a block of colour. The presentation also described recent progress in the monitoring of advanced multivariable controller performance.

A talk from UCL and BP (Margret Bauer, Nina Thornhill, and Adrian Meaburn) described how they detected and diagnosed a plant-wide disturbance in an industrial process that was leading to loss of performance in many control loops. The basic idea is automated clustering of measurements whose time trends have similar power spectra. The diagnosis step used a cause-and-effect analysis to show that the presence of a recycle was the reason for the persistent upset. The BP author explained the thinking behind the decision to implement an advanced multivariable control scheme and how the analysis helped in making the decision.

Batch processes are important in the manufacture of high value specialty chemicals. The focus on continuous processes has, however, left CLAD for batch processes still to be addressed. The challenges of adapting CLAD for batch processes were described in a presentation from Expertune (Richard Barraclough). They have identified and solved basic problems in the batch area such as the synchronisation of CLAD assessments with the activity within the batch. The end result is a system which will do performance assessments only at relevant times and not, for instance, during filling and emptying. Another consideration is that different products are made on the same equipment, quite possibly requiring different benchmarks. The talk also showed how the non-steady nature of a batch process such as set point changes can be exploited to give information about the process.

NEW DIRECTIONS IN DIAGNOSIS
Honeywell Hi-Spec Solutions has prioritised research directions for control loop diagnosis. Their industrial survey in 2001 reported that many control loops classified as having poor or fair performance have valve problems, so valve diagnosis was a high priority. Since 2002 there has been an intense research effort into the detection and diagnosis of faulty valves and there are now several methods available. Other research directions with a high priority are automated causal analysis, performance change detection, and the plant-wide approach of behaviour clustering to identify groups of measurements with similar time trends. Several of the seminar speakers described progress with these priority topics.

A new method for on-line detection of developing faults was presented from Migma Systems (Bo Ling). It detects changes using a non-parametric method (that is to say it makes no assumptions about statistical distributions) with applications both in the performance monitoring of control loops and in the monitoring of equipment such as pumps. The method detects clustering patterns in the recent past history of a measurement and looks for changes in the clustering pattern.

A presentation from Oxford University (István Gyöngy and David Clarke) challenged the traditional passive methods of CLAD that use only data from routine operation. The concept is an active CLAD monitor that gains a great deal of useful information by injection of a test signal into the loop but using a low signal-to-noise ratio that keeps disruption to a minimum. A benefit of active monitoring is that it specifies the direction in which the controller parameters should be adjusted for improved performance. The methods have been demonstrated practically on a laboratory test rig where they worked well in improving the performance of a flow loop which deteriorated at low flow rate.

A talk of from the University of Hull (Ron Patton and co-authors) concerned fault detection and isolation algorithms based on data-driven modelling methods which compare model outputs with the measurements from the process. It presented benchmark cases for the evaluation of such algorithms, one based on detailed modelling of an actuator with simulated fault conditions and one based on data from a sugar-making process in which faults were deliberately introduced into the process. These benchmarks are available from: http://diag.mchtr.pwedu.pl/damadics/benchmark.html

Mitsui Chemicals (Toru Matsuo) has been using wavelet transforms to display the frequencies present in process time trends.
Control loop assessment

showed an upstream disturbance comprising a series of short, sharp shocks to a system becoming smoothed as it propagated through the process to the extent that it could not be recognised visually as related to the original disturbance. The wavelet transform, however, retained its features in the time-frequency domain and the similarity was instantly recognisable. A shift-and-match algorithm using time-delayed wavelet cross-correlation establishes the sequence of signal propagation. In a Mitsui Chemicals process it successfully uncovered the control loop at the root of a plant-wide disturbance which disappeared completely after retuning of the loop.

WHAT’S AVAILABLE?

Typical ways in which controller performance assessment is delivered include products for sale and vendors using it as a service, either in the form of web-based service or as a tool to ensure good performance of the regulatory PID layer before installation of advanced model predictive control. Controller performance assessment and monitoring is generally being supplied with new distributed control systems, while older systems are also upgrading by adding such tools.

A number of controller performance systems are commercially available both from suppliers of distributed control systems such as ABB (Loop Performance Manager) and Honeywell (Loop Scout), as well as from independent suppliers such as Expertune (Plant Triage), ISC (PROBEwatch), Matrikon (Process Doctor), PAS (Control Wizard) and ProControl Technology (PCT Loop Optimiser).

End users are also reporting successful in-house systems, for instance the Eastman Chemical Company has its own system with web-based links to all Eastman’s DCS systems, monitoring the performance of many thousands of control loops worldwide.

There are many benefits from using controller performance assessment and monitoring, and more to come in the future as new methods for diagnosis and loop tuning advisors start to be included in the tools. The discussions at the IEE Seminar on Control Loop Assessment and Diagnosis suggest it is a valuable technology in the process industries. End users who adopted early have reported good returns and benefits on their monetary and time investments, and others who are arriving late may now have some catching up to do!

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