BUTTERWORTH HEINEMANN

J. Proc. Cont. Vol. 5, No. 6, pp. 399–400, 1995
Elsevier Science Ltd
Printed in Great Britain
0959-1524/95 $10.00 + 0.00

Letters

Dear Sir,

A statement made in a journal article by Hovd and Skogestad[1] appears to be inconsistent with industrial practice. In their introduction, the authors posit that 'decentralized control remains popular in the chemical process industry', despite developments in multivariable control. In this letter, I would like to submit evidence and arguments that contradict this statement.

In the following, the chemical process industry is taken to encompass the refining, petrochemical, natural gas processing and ethylene industries, collectively known as the hydrocarbon processing industries (HPI). Furthermore, decentralized control is understood to apply only to the supervisory control layer, i.e. the layer that lies above the regulatory single-variable PID flow, pressure and level controllers[2], which are trivially decentralized. These assumptions are justified by the fact that all the examples used to illustrate decentralized control in the chemical engineering literature are drawn from supervisory control problems within the HPI.

In a world-wide survey of purveyors of multivariable predictive control (MPC) technology, Froisy[3] has identified no fewer than 300 multivariable control applications in the HPI, including 80 on fluid catalytic cracking units and 70 on ethylene plants. Papers documenting these applications are presented yearly at industrial forums such as the NPRA conference and in trade journals such as *Hydrocarbon Processing*. The survey results must be regarded as conservative because end-users that have either licensed or developed their own MPC technology for internal use were not consulted. Several major international oil corporations are known to fall in this category.

By comparison, successful non-trivial industrial applications of decentralized control in the HPI are sparsely documented in the chemical engineering literature, if at all. Certainly, if decentralized control were as popular as Hovd and Skogestad assert, at least a few applications would be available for inspection and decentralized control would be an issue for implementors of MPC. Specifically, decentralized control success stories within the HPI would be aggressively advertised in order to enable this technology to compete effectively against the dynamic MPC industry. To the best of this writer's knowledge, no demonstration sites exist and decentralized control applications are never discussed, let alone presented, among practitioners of MPC.

The paucity of decentralized control applications should surprise no one. Decentralized control would be difficult to use in the HPI because of the restriction to square plants and the assumption that all controlled variables (CVs) are to be controlled to setpoints. The archetypal HPI multivariable control problem involves a non-square system wherein the majority of the CVs are constrained but do not require a setpoint and opportunities exist for manipulated variable (MV) optimization. The closed-loop performance limitation inherent to decentralized control is another barrier to its applicability given that the performance of a supervisory control strategy is tangibly tied to the revenue stream that it can generate[4].

In conclusion, there is evidence to say that, for practical reasons, MPC has and continues to enjoy overwhelming popularity over decentralized control for supervisory control applications within the HPI.

Pierre Grosdidier
Setpoint Inc., 14701 St. Mary's Lane,
Houston, TX 77079-2995, USA

References

1 Hovd, M. and Skogestad, S. *J. Proc. Cont.* 1993, **3**(1) 43
2 Grosdidier, P., Mason, A., Aitolahti, A., Heinonen P. and Vanhamäki, V. *Comput. Chem. Eng.* 1993, **17**(2) 165
3 Froisy, J. B. ISA, paper #93-370, 1993, 1249
4 Latour, P. L., Sharpe, J. H. and Delaney, M. C. *ISA Trans.* 1986, **25**(4) 13

Dear Sir,

In his letter Pierre Grosdidier claims that decentralized control enjoys no popularity in the chemical process industry. Since the conventional wisdom being taught in process control courses throughout the world is exactly the opposite, this statement at first seems startling, especially since it comes from a person with a broad industrial background. Fortunately, a more detailed study of his letter reveals that the apparent disagreement is more a matter of words. First, Grosdidier only considers supervisory control (above the regulatory flow, pressure and temperature controllers which he regards as 'trivially decentralized'). Second, he limits himself to square plants, which is a special case of decentralized control, although it is the one which has been most widely studied in the academic literature. Since we are worried that the misconception may spread in the control community that further research in the field of decentralized control is futile, we shall below explain our views in more detail.

First we need to define decentralized control. The word decentralized means something that is not centralized, and one can therefore conclude that a decentralized controller bases its control computations on only a subset of the available information and affects only a subset of the available manipulated variables. Actually, with this definition all multivariable control applications so far reported in the process industry are decentralized, since these applications invariably are limited to a subsystem of the total plant, for example, to the fluid catalytic cracking unit. Such an interpretation is too broad, so let us for the remaining discussion focus on decentralized control using single-input single-output (SISO) controllers, usually of the form:

$$u_1 = K_1(s)(r_1 - y_1) \quad (1)$$

where K is the controller, u is the manipulated input, y is the process output and r its reference value (setpoint). In spite of what one might believe from Grosdidier's letter this is by far the most common control structure used in the chemical process industry. It may look like it is not possible to handle nonsquare systems with SISO controllers. However, since the input to the controller in Equation (1) is a setpoint minus a measurement, we can cascade controllers to make use of extra measurements or extra inputs. For example, the output from one controller may be the setpoint to another (for the case with an extra measurement):

$$u_2 = K_2(s)(r_2 - y_2), \quad r_1 = u_2 \quad (2)$$

Correspondingly, the output from one controller may both be a signal to an actuator as well as a measurement for another controller (for the case with an extra input):

$$u_3 = K_3(s)(r_3 - y_3), \quad y_3 = u_1 \quad (3)$$

Selectors and logic switches are used for cases with more controlled variables than manipulated inputs. Also, the use of selectors, on-off controllers or controllers with a high gain allow outputs to be controlled in certain ranges rather than at their setpoints.

However, these systems can easily become very complex and difficult to maintain and understand, so if a good process model is available, it may be both simpler and better in terms of control performance to set up the control problem as an optimization problem and let the computer do the job, resulting in a multivariable controller. Indeed, as discussed by Grosdidier the use of multivariable control is now widespread in the process industry.

If this is the case, why is decentralized control still used in most cases? The main reason is the cost associated with obtaining good process models, which are a prerequisite for applying multivariable control (admittedly this is not the justification given in most papers on decentralized control). Furthermore, these models must be maintained and updated, and the formulation of the multivariable control problem modified, whenever changes are made to the process. On the other hand, with decentralized control each controller can be tuned with a minimum of modelling effort or on-line by selecting only a few parameters (e.g. gain and integral time constant).

We do not want to engage in an anecdotal discussion on 'successful non-trivial industrial applications of decentralized control in the HPI'. However, as noted by Grosdidier, there are a large number of control loops which are 'trivially decentralized', so it goes without saying that there must also exist industrial control problems for which it is an issue whether one should apply decentralized or multivariable control.

An important challenge when designing decentralized multi-loop control systems is to find a control structure where the loops interact only to a limited degree (the pairing problem). This allows the controllers to be tuned independently, usually starting with the fast loops. One requirement is that the sign of the gain of the loop is known and does not change. The RGA is a very useful tool since negative RGA-element indicates a pairing where this may happen and the benefit of decentralized control is lost. Since decentralized control depends on feedback rather than models as its main source of information, it is also more important (relative to model-based multivariable control) that the control loops respond quickly.

In terms of future research on decentralized control, there is a need for better tools to assist the engineer in finding the best structure, for example, for non-square plants. There is also a need to evaluate what performance can be achieved by decentralized control for various problems (processes), so that the benefits of applying multivariable control can be assessed. Finally, it is important to consider design of the process (and not only its control system), with the objective to design plants which are easier to control and less sensitive to disturbances (better self-regulation). For multivariable control, a main challenge is to reduce the cost of obtaining models.

In conclusion, the main justification for applying decentralized control is that it allows tuning without the need for a process model describing the detailed dynamics and interactions in the process. Multivariable controllers may always outperform decentralized controllers, but this performance gain must be traded off against the cost of obtaining and maintaining the process model needed for multivariable control.

Sigurd Skogestad and Morten Hovd
Dept of Chemical Engineering
University of Trondheim - NTH
N-7034 Trondheim
Norway