The Nuclear Industry and Digital Control: An Unrealized Opportunity

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Digital computers have been utilized to upgrade performance and safety through automatic control in raw materials processing, fossil-fuel power, aerospace, and other industries. The effectiveness of these systems for reliable sensor-oriented control of complex operations is well established; in most cases, the question is not whether but how best to use the technology.

The story in the commercial nuclear power industry is different. To date, there has been little substantive progress in employing digital computers for continuous supervision and regulation of nuclear reactors or the associated power plants.

Proposals to employ computers for these applications are not new, of course. Arguments were voiced at least fifteen years ago that reactor performance and safety could be increased substantially by raising the level of automation at nuclear generating stations (Ref 1). A review of papers presented at International Atomic Energy Agency symposia, performed more than a decade ago, revealed broad-based anticipation among participants that computers would be assigned increasing roles in nuclear plants and realization that the uses of these automated digital controls could be beneficial (Ref 2). However, there was no consensus at the time on what the computers would do, and no perceived need for closed-loop control. These findings, unfortunately, remain valid today.

Still, although events such as the Three Mile Island accident have forced the nuclear industry to examine the possible utilization of computers for reactor control, the focus is on open-loop systems for tasks such as safety parameter display. The feasibility and desirability of advanced feedback control are only beginning to be explored (Ref 3) — in spite of many strong supporting arguments.

1. An integrated multivariable control strategy should yield better response than the present sets of highly-interacting individual analog loops. For example, algorithms could account for relationships between feed pump discharge pressure and steam generator level — which are now regulated by entirely autonomous controllers.
2. Multivariable strategies — combined with functions such as fault detection, transducer calibration, and measurement estimation — would increase control system robustness relative to sensor and actuator failures. As an illustration, a system could change control modes or even revert to predetermined safe setpoints if designated input or output actions became unavailable (Ref 4).
3. Assuming that nuclear plants will be operated in load-following modes in the future, closed-loop control would make it possible to predict and avoid the skewed power profiles that could result from spatial xenon oscillations. One utility currently planning to operate in this manner is developing computer software to advise licensed operators of the proper sequence of control mechanism manipulations — but not to take the next step and perform the actions automatically (Ref 5).
4. Optimized multivariable dynamic reactor control strategies implemented on fault-tolerant digital systems could supervise and regulate large numbers of widely-ranging variables and respond rapidly to changing demands or operating conditions (Ref 6). Such systems could anticipate disturbances and act to prevent upsets, or detect and damp out or compensate for local fluctuations before they grow or propagate through the plant. This would not only improve efficiency by stabilizing operation, it would also minimize the likelihood of both spurious shutdowns and the need for emergency intervention by protective safety equipment.
5. Assuming that sensors and analytical models are developed that yield accurate pictures of conditions within the reactor in real time, closed loop digital systems could make repeated fine adjustments to optimize in-core power distribution and fuel utilization.
6. Programmable digital control systems offer flexibility to be modified to accommodate future plant changes without expensive hardware retrofitting.
7. Digital systems can calculate and display or control variables that are not directly measurable. As an example, computers are currently used in boiling water reactors to determine average planar

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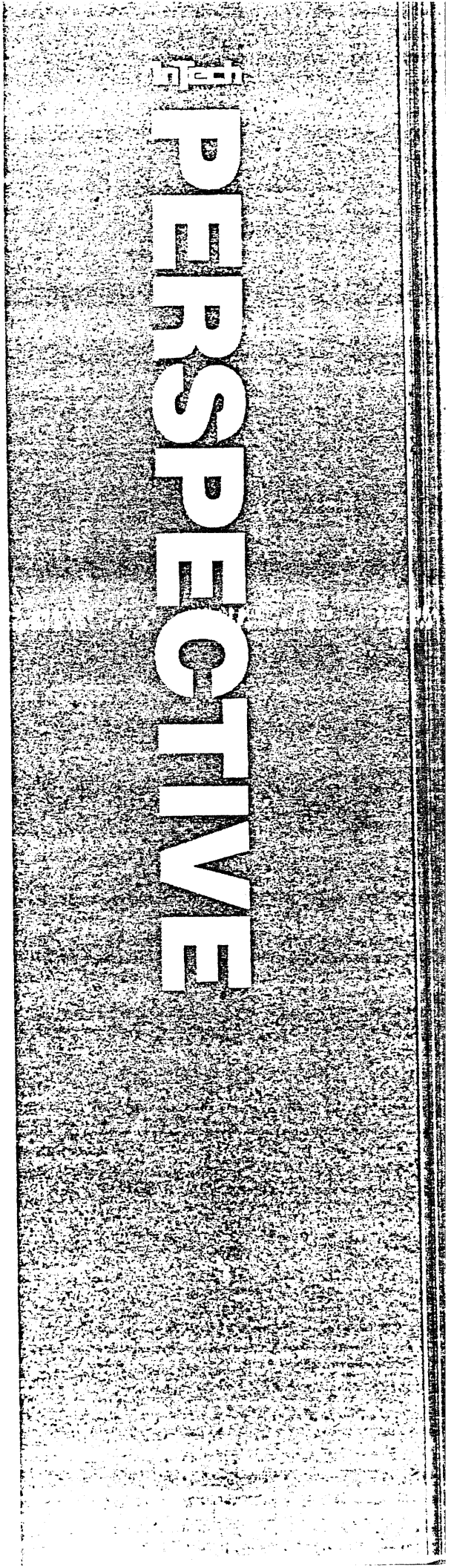

linear heat generation rate based on signals from in-core flux and temperature detectors. Subcooling margins and net positive suction heads are among the other quantities of interest that cannot be measured directly.

8. Closed-loop control would enhance ability to monitor and limit excess reactivity. This would be particularly important when a reactor is critical but at such low power that the magnitudes of the usual negative feedback mechanisms — temperature and void effects — are not physically significant.
9. A closed-loop digital system could account for the nonlinear effect of control rod movement — a phenomen resulting from rod worth being roughly proportional to the square of the normalized power profile and being affected by concentrations of short-lived fission product poisons. A system with this capability could prevent use of rods whose worths were temporarily abnormally high. This could be of use in hot-scram recoveries of boiling water reactors where, as a result of xenon-induced changes in the power distribution, the inadvertent withdrawal of peripherally-located rods of normally low worth can cause excessively short periods of local power peaking.
10. Data from infrequently performed operations such as heatups or cooldowns could be stored. Pattern recognition techniques could then be employed to help determine the most efficient operational sequences for different initial conditions.
11. A digital controller could maintain temperatures and pressures within specified limits to improve efficiency and safety during startup and other transients. This would be of particular value in pressurized water reactors when conditions must be tightly controlled to avoid potentially damaging combinations of thermal and mechanical stresses.
12. Computers can be programmed to accurately schedule and perform many of the routine checks and procedures now assigned to licensed operators. This can not only improve the degree of surveillance over monitored variables and help ensure that tasks are not forgotten or overlooked, but can also free the licensed operators to perform more critical jobs and concentrate on overall plant behavior (Ref 1).
13. Digital systems can scan, evaluate, and compare large numbers of signals, verifying operation or identifying potential problems essentially in real time — tasks well beyond manual capabilities. The licensed operators could then use their unique talents to diagnose the ramifications of problems identified in this manner.
14. Closed-loop digital control could enable licensed operators to monitor the plant without having to simultaneously manipulate it. It makes little sense to require a highly-trained individual to focus attention on adjusting a knob in response to one or two instrument signals, when a computer receiving the same information would make the same decision — and implement it faster and more precisely. Operators should use their knowledge and reasoning powers to survey broad operations, while computers attend to well-understood details.

Many reasons are given why the commercial nuclear industry has failed to adopt the latest technology for reactor and plant-wide automatic control. These include: traditional operation of nuclear facilities as base-

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loaded plants, emphasis on protective as opposed to control systems, design of most plants now operating or under construction long before the revolution in digital technology, lack of design criteria for control strategies (Ref 4), concerns regarding anomalous reactivity (Ref 7), issues relating to software verification and hardware reliability, and the possibility of non-licensed personnel such as load dispatchers being able to alter reactivity. These constraints must be acknowledged. But, the survival of the commercial nuclear industry may well depend on the ability to overcome them and implement advanced controls based on the latest computer technology. Other industries — including Canadian and Japanese utilities — have broken through their own technical, economic, and institutional barriers to computerization, and have profited by doing so.

Moreover, the ultimate irony is that as computers fall in cost and rise in power, they will certainly become common in nuclear plants for non-control functions — such as data logging, procedure referral, alarm sequencing, and heat generation limit calculation. As this occurs, licensed operators will become dependent on computer-processed information. The result will be that plants will be run on the basis of computer-generated outputs — even if they are passed through human operators. Wouldn't it be better to introduce digital control hardware and software technology in a planned, systematic manner?

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InTech

Who Will Own the American Instrument Companies? Hint: Look Abroad

ALAN KRIGMAN, Editorial Director

If you think that ownership of instrument companies doesn't affect the products, services, and prices available to users, think again. Leadership in this field — for better or for worse but certainly for sure — has been vested with the vendors since time immemorial, give or take a year. So there is justifiable cause for concern when mergers, acquisitions, and other financial fandangos are afoot.

We've already had a dose of instrument companies being traded. The incentives for the buyers, of course, have been in making investments they hope will pay off in the future. And the buyers, to date, have understood (but typically underestimated) the need to fund development of technology and market position. The net result to users has been generally beneficial. We could all name systems — maybe even companies — that wouldn't exist today except for fiscal faith on the part of some cash-rich squirrels putting away acorns for the winters of their traditional businesses.

Another round of acquisitions may now be looming. You have surely heard the rumors about some of the major instrument companies being

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