Use of Microelectronics to Upgrade Process Control into Production Control

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ABSTRACT

Process control in oil extraction and processing is traditionally done by independent control loops and logic (sequence) controls. In the best case, all controls are located in one central control room. The operator's task is to draw the right conclusions from the process conditions signalled to him, to coordinate, to plan and to keep log-sheets. On the basis of this information, he can coordinate between control loops and optimize unit operations. With the application of modern microelectronic-based control systems (integrated control systems), it is possible to present the operator's information on a higher level (e.g., yield figures and energy consumptions computed from basic data), to do computerized planning operations and updatings, and to retrieve data which are used as an input for accounting systems and management information systems. Underlying principles, means for implementation, as well as benefits (both proven and potential) are described. The available hardware and software packages hardly form any limitations; on the contrary, we must often limit ourselves to optimal use of the available tools and not fall into the trap of "maximal automation." Our aim is not to automate and control as much as possible, but to use automation as one of the means to process oilseeds and edible oils with the highest possible efficiency.

INTRODUCTION

In the last two decades, considerable changes have taken place in the control means which are offered by the instrumentation and control companies and have been introduced in the process industry. Pneumatic controllers were widely replaced by the electronic equivalent, and relay logic for interlocks and sequences has been replaced by solid-state logic, which in turn is being replaced by programmable logic controllers. Up to this point, analogue and digital controls followed their own individual path of development with very little crossfertilization. This has changed with the advent of distributed control systems in the last few years. These systems combine analogue and digital control functions in one approach (1,2).

In broad lines, the development can be characterized by the following phases. Up to 1970: controllers were individual units, mostly pneumatic; all functions of a control loop were combined in one panel instrument; the number of display and operating units was equal to the number of control loops; interlocks and sequential logic were performed by relay or hardwired logic; and the controls for one process were combined in one panel; several panels sometimes combined in one control room.

From 1970 to 1975: the first generation of process computers was introduced; all analogue and sequential controls were done in one control unit; conventional panels were still widely used for manual back-up and display; and programmable logic controllers were introduced.

From 1975 to 1982: the lower level of programmable logic controllers and the upper level of computer control have been combined in control networks ("distributed control", "integrated controls").

COMPUTER-DEPENDENT CONTROL SYSTEMS

The control networks of systems using process computers are built up according to three principal schemes: central computer; star-type network; and highway-type network.

Central Computer

In this case, see Figure 1, all process units are directly connected to one central computer. Each individual function of the unit operations has its input/output in the interface part of this computer, and all control functions are done in this computer centrally.

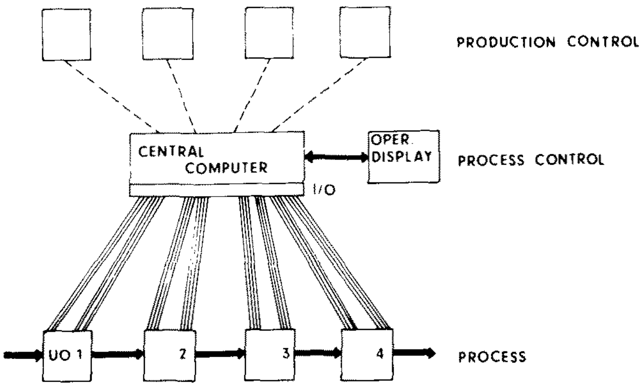

FIG. 1. Process computer system with one central computer.

The advantages of this approach are: all process information is available in one unit; any program or control is possible; and complicated data handling can be done, since considerable computing power is available.

The disadvantages are: stepwise installation is difficult, if not impossible; a clear specification must be available prior to installation, since programming is complex; all software has to be purpose-written and is necessarily a matter for specialists; all unit operations depend on one control unit; and high availability is only achievable with double units.

But, at the time of introduction of this type of system, it was the only solution. The central computer is still a good approach for large continuous plants which are well known in all details and which are not likely to be changed, neither in the process, nor in the control set-up. This approach is therefore widely used for the processes of the chemical and petrochemical industry, and to a lesser extent in the oilseed and edible oil industry.

Star-Type Network

Whilst the central computer approach combines all controls in one unit and on one level of control, other approaches distribute the control over various levels and also over a number of units. In Figure 2, each unit operation is equipped with a control unit (level 1). This process control unit covers all basic functions of control which are necessary to run the unit operation.

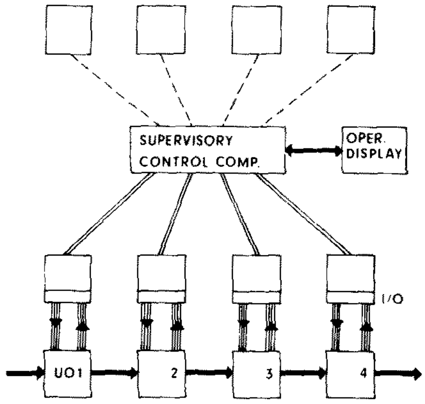

FIG. 2. Star-type process computer system.

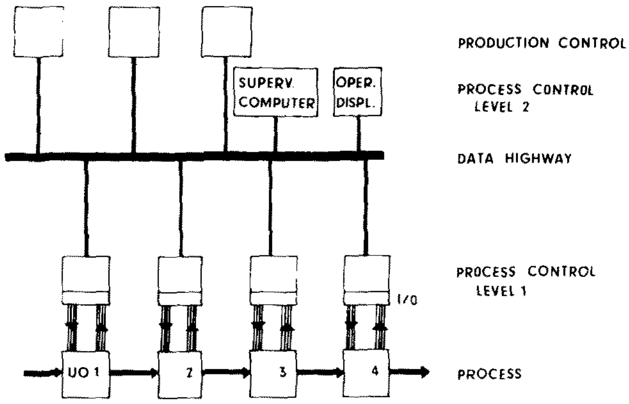

FIG. 3. Highway-type process computer system.

The basic functions are: analogue control of the process variables (temperature, pressure, flow); digital control of process equipment (start/stop of motors, open/close of valves); and alarms, interlocks. These functions may be extended with: sequential logic (for batch processes), and recipes (sequential operation with variable parameters, or calculations of parameters) (3). The individual process control units may or may not be equipped with local operator stations.

Coordination between the control units of level 1 is done in the supervisory control computer, level 2. The controllers of level 1 report to this computer via a data link. This data link is bidirectional: data from level 1 are transferred to level 2 and level 1 receives orders from level 2. The task of level 2 is coordination between the units of level 1, and providing a comfortable operator's interface through which the local controllers can be supervised.

The advantages of the distributed approach are that: the modular distribution guarantees a high availability (in case of a failure in one process controller, only one unit operation is affected); the investment can be phased (start with one or several units on level 1, then extend to other operations or to level 2); changes in one part of the control network do not affect others; and standard programs can be used for the unit controllers (application by process engineers) (4).

Disadvantages are that: the communication links between the level 1 modules and the supervisory computer are tailor-made; the software for the supervisory computer is completely tailor-made; and extensions have to take care of the fact that all communication links between level 1 modules go through the higher hierarchical level.

Highway-Type Systems

Another (more recent) approach to a distributed control system with modular units is the highway principle (see Fig. 3). The dedication of level 1 process control units to the unit operations is the same as for the star-type systems. The communication between each other and the supervisory computer, however, is realized by a common data highway ("bus") to which all local units and the supervisory computer are linked. The local units of level 1 can communicate with each other via this highway without any involvement of the higher level. The same highway is used to connect the level 2 units with each other and the level 1 units. Communication via the highway can be initiated by the unit which requires the communication, whether it is the higher level or the lower level machine.

The traffic on the highway and the access to it is strictly formatted. The highway hardware and software has, therefore, a strong influence on all modules of the system.

The advantages of the highway approach are: high availability by modular approach, easy phasing of investment, easy extendability on all levels, standard software for the unit controllers and partly for the supervisory unit, and standardized communication on all levels.

Disadvantages are: higher price (compared with star-type systems); and reduced flexibility—tailor-made programming only possible in some parts of the supervisory computer.

FROM PROCESS TO PRODUCTION CONTROL

The descriptions given above concentrate mainly on the process control part of the systems: control of the operations of one process unit and supervisory control of a number of process units. These control levels are completely adequate to run a process in accordance with a given set of process parameters, provided these are known. Optimal running of the total process, however, depends on long-term optimization of this set of parameters.

Conventional Process Optimization

Up to now, process optimization by variation of parameters is generally done by the production management on the basis of historical data. These data result either from recordings of process data produced by the process control units or from condensed information provided by the supervisory computer. This manner of optimization will always be behind the facts and can therefore only be used for long-term adaptations of the process. In case of short-term deviations, necessary corrections are too late to be effective. Take, for instance, a process in which the process parameters have a strong influence on the energy consumption. In this case, long-term optimization can only be a careful extrapolation from historical data (also long-term). If short-term deviations occur, an immediately available specific energy consumption figure is of invaluable help. By specific energy consumption figure is meant, e.g., tons of steam per ton of product, and "immediately available" must be regarded in relation to the speed of change and the process dynamics: it could be in the same shift, within one hour, or during the processing of one batch.

Process Optimization in a Computer-Supported Control System

All inputs for calculation of specific consumption figures are present in a distributed control system, and the necessary algorithms for the calculations can be easily developed. Such a calculation is a typical example for the tasks done on the production control level. It is not directly necessary for process control, but supports the process operator in optimizing the controls on the process control level. The production control level can be defined as the combinations of all tasks which contribute to better processing, but do not directly influence process control.

A number of disciplines are involved in this production control, such as (see also Fig. 4): production management, planning, quality control, and process administration. Each of these departments has different requirements and a different input, but the common denominator is that they all operate with information from process control and give service to process supervision.

Production Control Functions

This section is an attempt to give descriptions of typical functions in production control. Their relative importance will vary from application to application, and some may be irrelevant for certain operations.

On the other hand, there may be production units which require production control functions not mentioned here.

Production management. It is the interest of production management to keep the processes at a constantly high efficiency level. For this purpose, rapid feedback is more important than absolute accuracy of the figures: an efficiency figure with ± 10% accuracy which is available within some minutes is more appreciated than a ± 1% result which is presented at the end of the day.

The type of efficiency calculations needed by production management are, e.g.: crude feedstock consumption per ton finished product; energy and ingredients usage per ton, per hour, per batch; and product quality related to processing conditions.

These efficiency figures are used on the one hand to steer the production in the short term, and on the other hand they form a data base which is used for long-term process development and recipe modifications.

Planning. In a production with a number of interrelated unit operations, with a mixture of batch and continuous process, and with dependence upon common services, good planning is vital for the day-to-day operation. Planning and production scheduling is determined by product demand, and is dependent upon raw material position and availability of equipment and personnel.

A planning scheme which is once made on the basis of available capacities (say for one week in advance), has to be adapted by the feedback from actual production and buffer stocks, which may have been influenced by stoppages or varying production speeds. Feedback of the actual production progress consists of information which is available in the level 1 process controllers: status of a production batch, actual throughput of a line, buffer stock situation. This information has to be processed and to be presented to the planning department in a form that makes it suitable for steering of the production.

Planning itself is either a human function, which communicates with the control system (rather than exchanging written schedules and log sheets with the process operator), or else it can make use of simulation techniques to establish an optimal program. This can include, besides the occupation of process equipment and the availability of feedstock and intermediates, optimal use of services and energy.

Quality control. The quality-control department serves production with information on analysis and properties of crude, intermediate and finished products. The flow of information from the process to quality control consists of on-line quality measurements and of samples taken on the factory floor which are analyzed off-line. One of the main tasks that a control system has to fulfill in this region

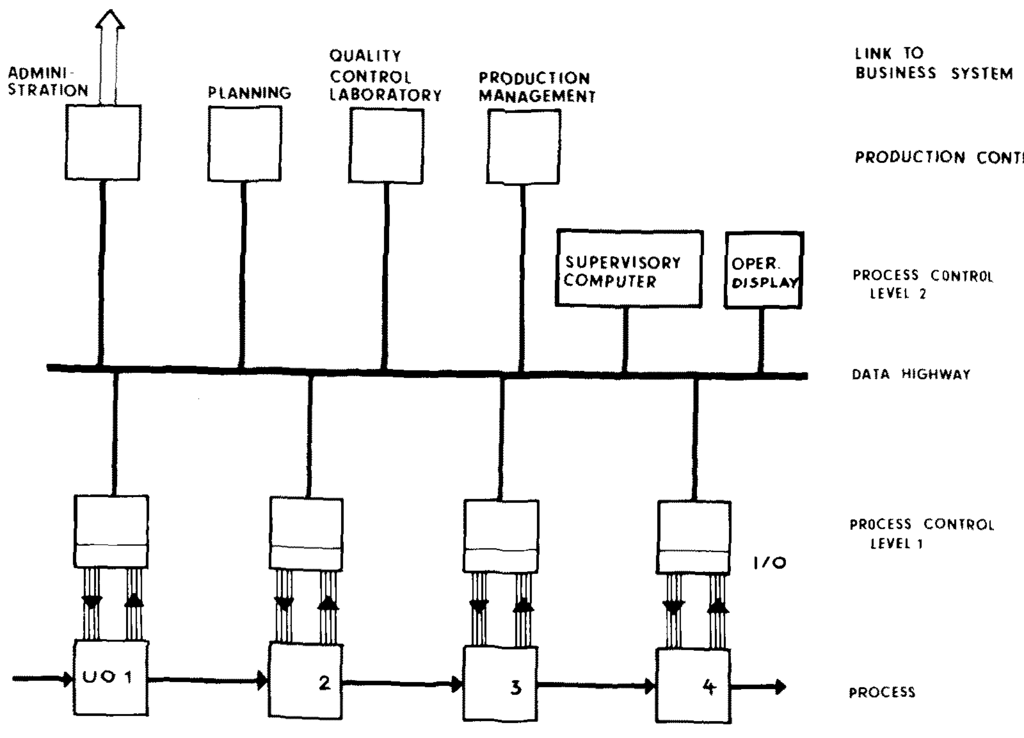

FIG. 4. Process with two levels of process control and some production control functions.

is sample coding and a quick feedback of results to the production. Where appropriate, the results are computed in quality statistics or are compared with long-term trends (5).

Production administration. The production-oriented accountant functions process production data to produce reports for production people about production. The data originate from production and are processed in a way to give insight into total production of finished material, consumption of energy and ingredients, etc.

The lowest and most detailed level is the report for the operator and supervisor, giving all data for a short period or a batch. Reports for production management are more condensed and may have the form of reporting-by-exception.

More consolidated reports are prepared for the commercial function, giving full insight into overall production and efficiencies, raw material usage and service utilization. This normally falls outside the scope of a process and production control system and is executed in the form of data transfer link to a business computer system.

Other applications. The above-mentioned examples of production control with information from a process control system are almost generally applicable to any oilseed or oil processing unit. Other more specialized implementations comprise: (a) Machine efficiency monitoring: operating data of machines are recorded on-line (actual speed, running time, downtimes specified for reasons) and condensed into an efficiency report. This information is used to steer the maintenance effort, or to investigate the influence of operational/mechanical changes, and to establish basic data for production planning. (b) Storage optimization: raw material position, product demand and production capacities are processed in a simulation model with the aim of stock minimalization or optimal planning. (c) Personnel resource planning. (d) Energy peak shaving by anticipation.

APPLICATION ASPECTS

The extra dimension of production control which is opened by advanced control systems, is not limited to a certain application. The approach is applicable to any manufacturing process. The biggest advantages are, however, achieved in processes which consist of a large number of unit operations.

Application in Oilseed and Edible Oil Processing

In our industry, the applications range from seed storage and oil extraction via refining and hardening to margarine and shortening production. The more complex the operation, the more evident are the advantages. We expect in the near future more and earlier applications in refineries and margarine factories than in oil extractions.

At the moment, we do not know any factory where a complete process and production control system is implemented. There are many examples where a complete distributed process control system of the level 1 type is operational (see Fig. 5). Only in some cases, however, one or another extension to production control is made, or a link to a business computer is established. But we think that the time is ripe for wider introduction of production control, and that we have the tools for its implementation at our hands.

Cost/Benefit Aspects

The modular structure of control systems, which makes a phased investment possible, will help to pave the way for their introduction. The crucial question will, however, be the financial justification of the investment. It is typical, that there is no one big saving factor to be achieved with the step from process to production control, but that there are a number of quantifiable or semiquantifiable savings.

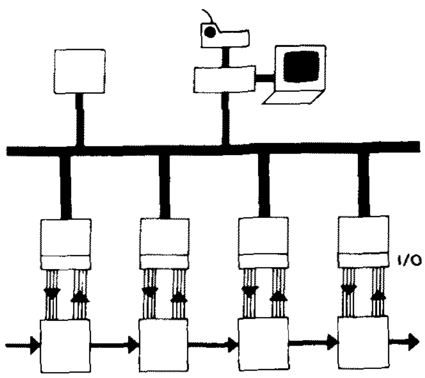

FIG. 5. Process with distributed controls and central operator station.

Apart from the straightforward benefits, such as labor saving in the administration by simplified data-handling, energy saving by more optimal process control, and more flexibility due to better overview, there are some minor benefits which each on their own would not justify the higher level of control, but which all contribute to the positive side of a cost benefit analysis.

The strictly reproducible process conditions, the adaptation of process parameters to changing conditions, and the quick operator information have a number of influences: the product quality is kept more constant; costly corrective treatments are avoided; and yield and energy consumption can be permanently optimized.

This necessitates, of course, that the operators make good use of the possibilities they have. They are less involved in control routines and do more management by exception and process optimization: the operator's role changes from direct process control to a supervisory and corrective function with coordinating responsibilities.

Masterplan Approach

In our present situation, it will be the exception that a green field complex will be erected and that we have to design a control system which covers everything, which has a horizontal span over all unit operations and which will cover all levels of process and production control. More frequently, one or more unit operations in a factory are replaced by more modern ones and these are, of course, equipped with modern controls. Replacement of other unit operations at a later stage or the modernization of their controls will result in a horizontal system expansion. Expansions in depth, i.e., from process control level 1 to level 2 and to production control, may be implemented at the same time or independently. A control system with higher modularity will clearly be favored for this kind of phased investment.

The high modularity should not tempt us to start a phased investment with a first step which is justified in its own right, without looking at the implications on further stepwise investments. Certainly, it is unnecessary to design the complete system in width and depth in all details before the first step is done. This is even not desirable; future steps may have to be reviewed in the light of process performance and further technological development.

We apply in such cases a masterplan strategy, the main aspects of which are the following: all unit operations of a site are reviewed with respect to their process technology and production related activities. Not only the present situation, but also unit operations which are likely to be installed/replaced/modified in the next 5-10 years are mapped in this way.

As a next step, the control requirements of each unit operation are described, with particular emphasis on links to other units and to other levels of control. The use of this approach is twofold: the requirements for a control system to be installed can be clearly defined and lead to a well justified selection of the type of equipment. Second, a network of interfaces is defined, within the limits of which the controls for one unit operation can be filled in. The "filling-in" investments may start at any point of the network, or at several points simultaneously, and independent of each other; the imposed network guarantees the right interfaces and communications.

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