Process monitoring and control on-line in the food industry

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The potential benefits of using new sensors and control systems in the future automation of food processing operations are summarized. The use of automated systems can ensure improved quality, reliability and safety of operation, with plant and processes being easier to commission and maintain. Programmable controllers can perform all of the process control functions for each stage of a process. In addition, such programmable controllers will furnish information required by process operators and management to provide an integrated factory control and information system.

Keywords: Process control; sensors; automation; food processing

INTRODUCTION

Food processing involves changing the nature, composition or form of materials through controlled physical, chemical or biochemical changes to yield a marketable product. These changes may be effected by batch or continuous operations using appropriate instrumentation and control (CFDRA, 1983). Recent investment by the food industry in new plant and processes has increasingly involved the adoption of automated batch and continuous processes; and some examples of microprocessor applications are shown in *Table 1* (Brown, 1987; Kelly, 1988).

SENSORS

Examples of the physical and chemical parameters influencing these processes and that must be monitored are shown in *Table 2*. Many different types of sensor exist for measuring each of these parameters, such as pressure (Withers and Richardson, 1988). Sensors are becoming increasingly sophisticated due to the innovative approaches taken to tackle the problems. The sensors may be based on a variety of systems, such as ultrasonics, vision systems, NIR and electro-optics. For example, sensors utilizing ultrasonics have a variety of potential applications, including measurement of temperature in microwave environments and measurement

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Table 1 Examples of microprocessor applications (Kelly, 1988)

Microprocessor application
Chocolate coating
Ice-cream manufacture
Batch sterilization
Fermentation
Cheese processing
Sugar processing
Mayonnaise processing
Brewery
Bakery
Long-life juice
Poultry grading
Packaging inspection

Table 2 Examples of physical and chemical parameters that require monitoring

Parameters that require monitoring	
Temperature	Pressure
Viscosity	Density
pH	Conductivity
Composition	Moisture
Packaging defects	Weight
Flow rate	Coding
Foreign bodies	Humidity
Shape	Colour

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of food particle flow in aseptic processing plants (Richardson, 1989; Lenn *et al.*, 1989).

It is, however, important that the sensor has its primary sensitivity to the parameter of interest and not to something else. This can be the case in, for instance, microwave absorption where the attenuation can be a stronger function of temperature than moisture content under some circumstances. The parameter should, ideally, be in the mid range of the sensor, and the sensitivity and repeatability should be known over the relevant range. The sensor must be compatible with the process in terms of physical protection, hygienic design and cleanability. It is also important that what is sensed is relevant, in that it is representative of conditions and also representative and consistent in composition with the bulk of the material.

PROCESS CONTROL

To be suitable, a control system must be easy to configure or programme, be rugged enough for the plant floor, have built-in proportional integral derivative (PID) loop functions and include the required logic and interlock capability (Allen *et al.*, 1987; Richardson *et al.*, 1989). In addition, systems must also provide floating point mathematical functions, handle multiple recipes and possess report capability.

Today, there are several models of programmable logic controllers (PLCs) available that meet all of these requirements at affordable costs and in various sizes. In this regard, those PLCs far exceed the capabilities of the ordinary process control systems. For example, dozens of loops may be updated as frequently as every second while still scanning and controlling thousands of discrete logic points. Programmable controllers have improved since their introduction, when they were thought of only as an excellent replacement for relays. Today, PLCs are being used to control all functions of very complex and sophisticated processes. The PLC is being chosen for its low cost, east of use and excellent maintainability over time (Powner, 1987; Cossey, 1989).

The distributed process control concept commonly employed today is based on dedicated programmable controllers relating to each stage of the process stream. These programmable controllers perform all of the process control functions for that stage, receiving digital and analogue signals on the status of the plant variables from appropriate sensors. They process this information using applications programmes stored in the memory, and subsequently activate output devices which control the process variables.

Industry has begun to include dedicated electronics and programmable controllers as integral components of engineered products. As well as performing process control activities these programmable controllers will furnish information required by process operators and management. This array of programmable controllers is linked together via a data highway to which are coupled the supervisory computer, operator consoles for control of manufacturing, together with alarm displays (see *Figure 1*). The supervisory computer serves to optimize the plant performances, which it does by monitoring the individual controllers and revising their control strategies according to what is happening elsewhere in the process. The operator interface with the control system is via a console or

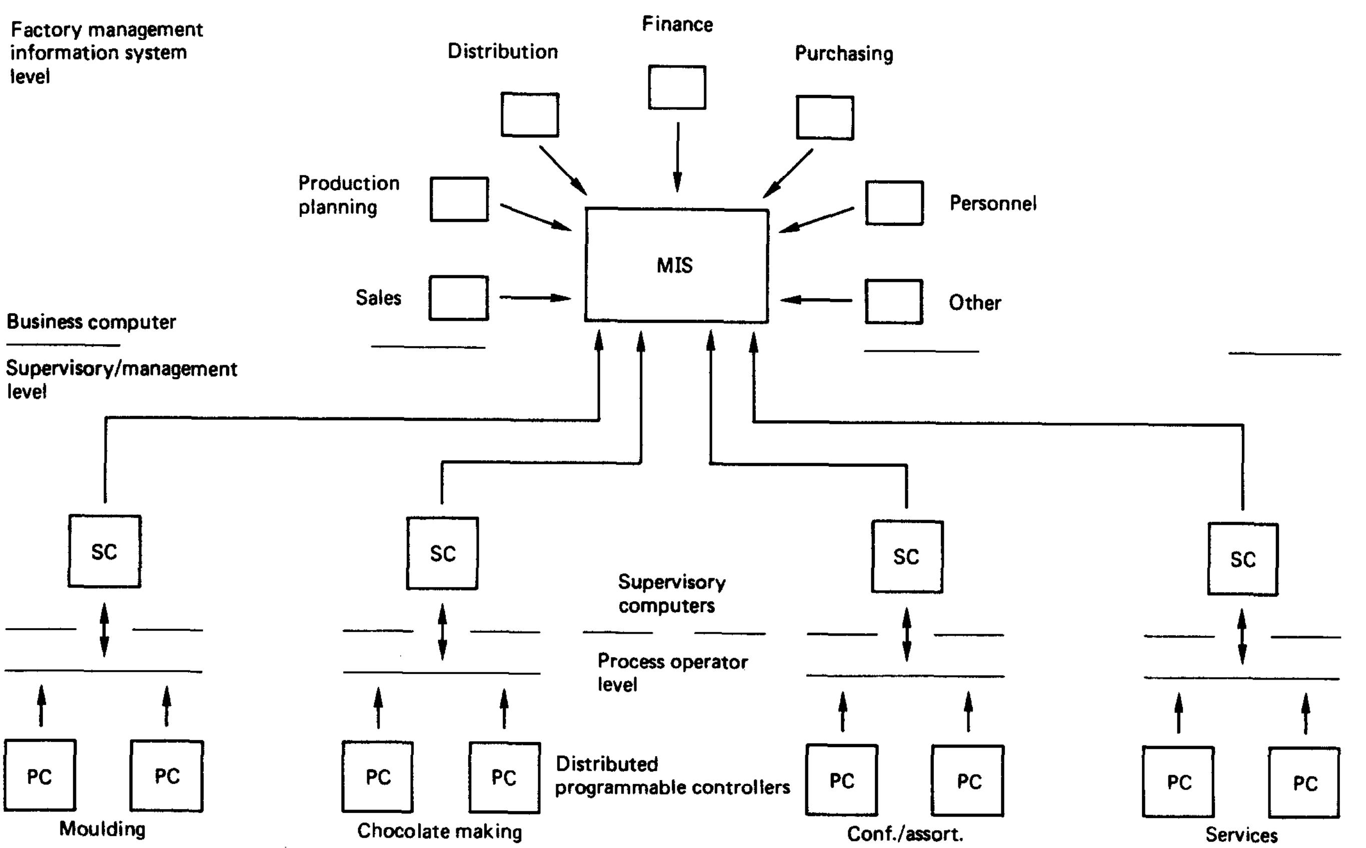

Figure 1 Integrated factory control and information system

work station comprising colour graphic screens and functional keyboards. Essentially, the purpose is to support the activities of the process operators by providing data of better quality and higher accuracy, facilities for trend information on selected groups of variables, and long term averages.

The use of PLCs coupled with databases is now being studied to develop intelligent expert systems capable of applying human-like judgements. Such studies are in their infancy, but those involved in this research believe that their impact will be significant in the optimization of processing operations, associated diagnostic activities and decision making.

AUTOMATION

Automation is commonly associated with a reduction in direct labour. Although this sometimes happens, there are usually other goals in the food industry, such as the following.

Quality

Consumers are demanding increasingly higher quality in the prepared food products they buy. Quality includes uniformity and consistency in the taste, texture and appearance of the product from one production batch to the next, whether it is a raw ingredient like flour or a finished product like bread.

Reliability

Most food processors know what they want to produce and how to do it, but mistakes can be made due to human error. These mistakes cost the processor money, either in unhappy customers, rework returns or scrap material. Automation controls provide a level of repeatability not possible with human operation, whether it is blending various flours to produce a desired specific mix, or setting up a bakery oven for a particular bread.

Safety

Beyond providing a quality food product that meets the customer's expectations, the processor is responsible for ensuring that the product is not harmful to human health. Automation can contribute to ensuring this achievement.

Flexibility

Most food plants produce several similar products through shared equipment. Without automation, there is usually a time-consuming changeover period while equipment and controls are adjusted for the next product. Automation allows this downtime to be minimized with a resultant higher plant throughput and greater utilization of fixed assets.

Maintainability

The food industry is changing rapidly to meet the market needs for new and different products. As new products are added, formulas changed or plants expanded, the control systems must be adapted to the new requirements. People may not respond well to change. They must be retrained, sometimes several times, before a change is learned or accepted. Relay-based control systems must be rewired or modified extensively, usually at a great loss in manufacturing time with a substantial manpower investment. Electronic controls may be quickly and easily reprogrammed in the office and the programme implemented with minimum inconvenience to the plant production schedule.

Installation and start-up

Installation and start-up of any new piece of equipment or control system requires time to check thoroughly, correct any mistakes or add anything that was forgotten. It has often been shown in the food industry that a control system using PLCs can be brought into full production status in a quarter to a half the time required by a system using the older styles of controls. In many cases the reduction in time to reach production can pay for much of the control system. This is particularly true for new lines or new whole plants.

Data collection

As operators strive to use plants more efficiently, better or more timely information on the plant performance is required. The traditional technician with a clipboard cannot keep up with this need for faster and more accurate data.

Most electronic control systems function well as data collection devices. From the control, the data can either be sent to a printer in raw form or to a host computer for further reduction and analysis into management information. Process monitoring and control can, therefore, be used in processing areas, on packaging lines, for materials handling, for warehousing, inventory and laboratory management (Selman, 1987; Marien, 1989).

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