Towards the lights-out brewery

A brewer's view of automation

The top man says 'We'll build a state of the art, fully automated brewery'. These have been mostly large developments, often on 'green-field' sites, where consolidation of facilities produces large gains in productivity and reduced overall cost. Can it be that only in such circumstances that the high cost of automation can be justified when the 'financial gurus' run the figures through their laptops?

By **Paul Buttrick**
Beer Dimensions

Brewers who have simple ideas to 'automate' and improve quality and reliability in a small section of an existing brewery often fail to justify their ideas in hard financial terms, and only sacking some of the few operators they have left will produce these hard savings. In this article, I will look back at how automation has developed in the last 30 years and at how it might develop in the future. There will be examples from my own experience as well as opinions and ideas for people to mull over as they strive for utopia in their own brewery.

A brief history of automation in breweries

I sat in an office in Warrington reminiscing on past times with Frank Ainsworth and Paul Mahony of CAL Systems. I had worked closely with CAL over many years at various Whitbread breweries, including Boddingtons. As the conversation continued, I began to reflect on some of the battles which I had had with brewery and project engineers in the past. We brewers were particularly hard on our pioneering engineering colleagues at times – do I sense a touch of guilt creeping in? Not really, I'm sure they questioned our parentage on many occasions!

Packaging lines and areas involving what I call 'stop/start, on/off' control had always been seen as very clever and automated, but brewing was undertaken by operators having special skills to regulate the processes that needed better measurement and control. Relay logic and solid state CMOS Logic figured in early control systems, with huge electric cabinets and mimic panels. The coming of automation meant that in the huge breweries of the 1970s could be built with sophisticated modern looking brewhouses hidden behind marble walls and 'space age' control panels.(Fig 1)

Much of the following process, except possibly CIP (in place cleaning), remained fairly manual up to the packaging line. The coming of the microprocessor gave rise to the first generation of PLCs (programmable logic controllers) bringing another major step forward. The program was entered into the PLC on something akin to a desk top calculator with a single line of text available to the programmer. Simulation was achieved by 'hard wired' connection of switches and lamps to the PLC inputs and outputs (i/o).

Brewers were told that 'anything was possible'; you could programme a microprocessor and the plant would automatically carry out the programme faultlessly every time. What we brewers did not realise was that the plant would work consistently every time, it took us a long time to understand that if any changes – some maybe very simple - had to be made, these 'chips' or EPROMs as they were called had to be sent away for reburning or reprogramming as we understood it.

In the mid 1980s, the arrival of the second generation PLCs (Fig 2) revolutionised automation and improvements in process control (P&ID-piping and instrumentation diagram control loops) really made full automation practical and flexible at plant level. Programs could be modified 'on the hoof' bringing with it a new set of problems in software version control.

Brewery plant

It was not just the control side which needed to improve to give full automation. Plant had to be designed and installed to give a fail-safe situation which did not spoil the beer

TOP: Figure 1: The past – a vast array of panels and knobs at Bass Runcorn's 'new' brewery in the 1970s

INSETS: Figure 1a and 1b: The present – all information is brought to a PC screen in the brewer's office as in Adnams new brewhouse or available out on the plant like this tiny Allen Bradley mimic panel at Oakham Ales.

Figure 2: A major step forward in automation and control in the brewhouse at Inbev's Magor brewery.

Figure 3: The original 1966 Tuchenhagen mixproof valve.
(Photo supplied by GEA Process Systems Ltd)

Figure 4: The 2007 version of the Tuchenhagen mixproof valve.
(Photo supplied by GEA Process Systems Ltd)

if a failure occurred. The introduction of the mix-proof valve was an enormous step forward which allowed large numbers of tanks to be hard piped and automated without risk of improper mixing or contamination with water or detergents.

I can remember that everyone wanted 'Tuchenhagen' valve matrices. Otto Tuchenhagen invented the mix-proof valve concept in 1966 (Fig 3, Fig 4) following an incident in Germany involving contamination of school milk. The range of valves still goes under the Varivent trademark name. The flexibility and control offered by PLCs, and mix-proof valve technology moved automation on from having the ability to work with less operators on bigger and more complex plant, to fully automated plant with operators having an overseeing brief ensuring the plant is working correctly and carrying out on-line quality checks.

Most modern brewhouses are essentially fully automated from raw materials intake to wort chilling with one person (or part of a person) inputting data and taking samples for analysis. Adding hops was one of the last operations to be automated, this remained manual because there was always someone around to do it, but dosing of extract and pellets has been automated in a number of modern plants.

Automated tanks

Fermentation has long been automated as far as controlling temperature has been concerned. A number of breweries have tried control on the basis of automated present gravity and pH measurement, but these have often failed due to inconsistent measurement as well as the cost of installation, maintenance and calibration of the instrumentation. Predicting the progress of fermentations has been easier and more productive than sophisticated control based on individual instrument readings.

Full auto-routing of fermentation and cold storage/maturation vessels is still rare apart from the most modern highly capitalised breweries. With up to half a dozen mix-proof valves needed per tank, the difficulty in justifying the spend cannot be covered by the normal 'hard' production savings (e.g. manning, losses etc). Decisions such as when to remove yeast, and where to, can be too complicated in all but the simplest plant. A 'lights out' fermentation and maturation area is therefore unlikely to be common in the near future.

Most large breweries seem to manage fermentation with very few people, and with some automation and pipework routing, could reduce the requirement to a single person per shift. Having said that, yeast propagation is an area where automation can be justified because precise control and complex operations are required to give consistency. For automation of tanks, many breweries make a decision based on residence time and frequency of valve movements. Bright beer tanks which may be filled and emptied a couple of times a day are the most commonly automated.(Fig 5) The modern BBT farm is often a 'lights out' area with everything from beer into tank, beer out to packaging line, blending and CIP being controlled by PLC.

Filtration

Filtration using vessel filters (screen and candle filters) were automated at an early stage (Fig 6). The closed nature of the equipment made for easy automation using hard wired systems backed up by a turbidity meter. The plants are normally manned by a single operator, whereas breweries which opted for plate and frame filters tended to be more manual and had more staff. Full automation of large plate and frame filters was trialled by a number and failed by all!

I have been involved in a number of potential filtration projects where the desire to move from a more highly manned plate and frame operation to a fully automated vessel filter plant, has failed because the financial justification did not stand up.

It seems that installing fully automated vessel filters could only be financially justified if a project was started from scratch, was volume driven, or the current plant grossly overmanned. With kieselguhr-free filters now establishing their credentials, and increasing problems with powder handling and disposal, we shall have to see whether breweries opt to jump from existing plate and frame straight to the new technology.

Justification for automation

In many cases, automation is specified to keep manning to a low level and to give a consistent operation. Previously a reduction in manning was one of the only acceptable hard benefits of investing in pipework and routing installation. The improvement in monitoring equipment has widened what is achievable. With capacity being tightly managed, time means product, so the elimination of dead time in processes is now measurable and thus more easily costed.

Automation and instrumentation for protecting the product – e.g. avoidance of contamination, with conductivity and pH probes on filling lines are far more easily managed in a fully automated plant where prescribed reactive processes can be programmed and automatically carried out. Beer losses often used to be costed on the basis of raw materials being lost, however the true cost should also include utilities and effluent charges, and in some tightly managed plants a labour element is included as well.

The impact of poor publicity on a brewery which pollutes the environment with an unauthorised discharge is huge and it would be wiser safeguarding its reputation with well engineered instrumentation and failsafe automated responses rather than leaving things to a conscientious but not infallible operator.

Cost of automation

Automation is still costly, but compared to 30 years ago is relatively more affordable. For example, in 1985, a 75 mm Tuchenhagen mix-proof valve and control head with feedback had a typical market price of £1261, compared to £1259 in 2007. Considering that costs have risen by

over 100% since 1987, the relative costs have reduced and the quality and reliability of the valve have increased substantially. Control equipment – e.g. PLCs, field instrumentation and programming have all reduced considerably in price since the early days.

A few tips for reducing automation costs

In my time I have become an expert in getting automation installed on plant where project engineers have been keen to keep overall costs to a minimum. Remember:

- When planning a project, take account of any future projects and install as large a PLC as it is reasonable to justify; this will reduce future automation and control costs. If this is not possible, make sure what is installed is easily adaptable and expanded.
- When looking at automation projects, take a really close look at how much plant is required. For example, how many tanks are required? Do we need three of these, can we work with two? The efficiencies afforded by automation very often reduce the requirement for extra plant; this cost saving can often be used to offset the cost of automation, especially when projects are engineered to a budget.
- Automation gives the opportunity to build in flexibility, but how much of this flexibility will actually be used and how often? Over-engineering is often the cause of projects being too expensive.

I recently visited a brewery with the most fantastic fully automatic yeast propagation plant. Every aspect was PLC controlled, with the absolute minimum of input required from the operators – except that the air supply for aerating the culture remained manual – not quite 'spoiling the ship for a ha'p'orth worth of tar', but a small anomaly on an otherwise perfect installation.

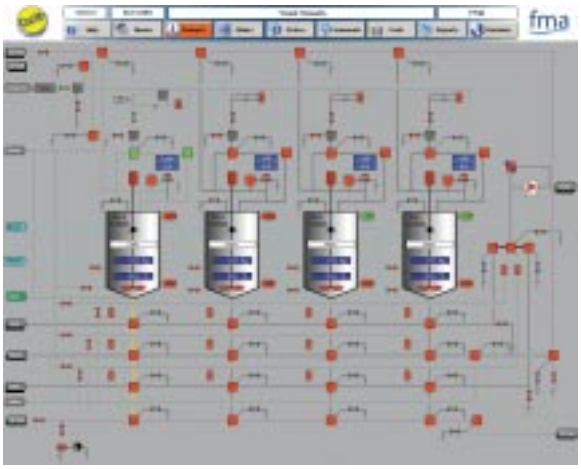
Trends

The improvement in process control instrumentation, plant schematics (Fig 7) and trending of parameters provides useful information for plant operators. In my experience, trending data has always been part of the requirement of any plant control system, but the information is not always used to its full effect. The control plant suppliers offer any number of parameters to trend, but these are not always configured on relevant pages and their scaling is often outside the useful range for quick and meaningful diagnostics.

An example of this might be trending of dissolved oxygen and temperature on a filtration plant. How often is a scaling seen as 0-10°C for temperature and 0 – 10 ppm for oxygen, when the target is likely to be 0°C for temperature and less than 0.10 ppm (100 ppb) for oxygen. I challenge people to go into their breweries and see whether their SCADA (Supervisory Control and Data Acquisition) trend graphs are optimally configured, I would only expect a handful of positive replies.

Figure 5 below: A modern Tuchenhagen valve matrix on a tank farm.

Figure 6 bottom: An automated filter plant at SABMiller's plant at Poznan in Poland.



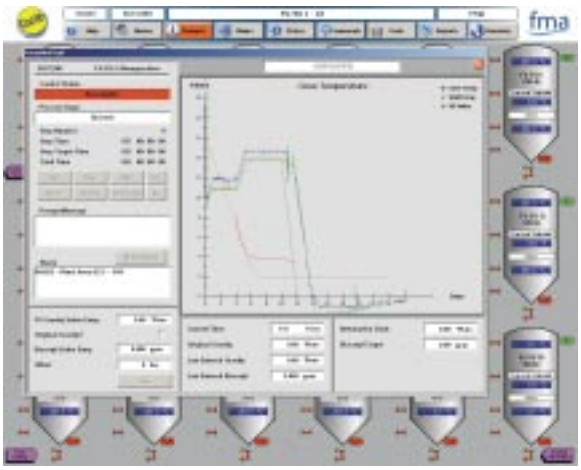


Figure 7 top: A SCADA screen showing graphics from yeast tanks.

Figure 8 above: Trend graph from a fermentation SCADA screen.

(Images: FMA Process Engineering Ltd)

Use of trending for plant commissioning

Trending (Fig 8) is often one of the last items on the commissioning plan – it's far more useful to have the trends properly set up early on to aid commissioning. One of my recent commissioning experiences was with some 500 hl/hr green beer centrifuges. The centrifuges would ramp up and down in flow according to the turbidity of the beer coming on to them. The start up procedure was set according to a pre-determined ramp rate, but the timing and set points were such that the average flow of the centrifuges was below the required capacity of the plant. The maximum flow was easily achieved, but time wasted in stopping/starting the centrifuges and tank changeovers, meant that the daily volume requirements were missed. Once the trend graphs on the SCADA system were configured and scaled correctly, the ramping up and down of flow rate could be improved to increase the average transfer rate from 300 hl/hr to greater than 400 hl/hr.

Trending for process improvement

In my opinion, a glance at a well configured SCADA trend screen is the quickest and easiest way to tell whether a process is under control. Each process will have a recognisable trend shape which, with frequent use, will be familiar to the operator. Any trace which is not following the right line or, has an unusual shape needs to be investigated and corrective action taken. Unless a problem is significant, it may otherwise not present itself until well after the event, so frequent monitoring coupled with a well thought out alarm system can significantly improve quality and efficiency. In normal production, trends are most useful for diagnosing problems, particularly when matched with sequence steps and process values. An example is trending for dissolved oxygen in processed beer, where any adjustments to plant and equipment are almost instantaneously recorded. Similarly plant faults, such a defective pump seal sucking in air, can be instantly picked up and rectified.

Utilities

My own early brewing world was dominated by malt extracts, losses, the laboratory report and packaging line efficiencies. I can remember being asked by Charles Tidbury, the then Chairman of Whitbread, how 'my wort attenuation limits were on Mackeson Stout?' Energy, water and effluent costs were well down the priority list. How that has changed, with these costs rising and now accounting for 20% of brewery costs. Legislation and response to global warming in the guise of IPPC (Integrated Pollution Prevention Control) permits feature highly. The IPPC permit may be looked on essentially as a license to manufacture.

With the requirement to introduce 'best available techniques' when practical, and demonstrate year on year improvements in performance, automation and monitoring in utilities becomes justifiable. As with all these things, a virtuous circle is formed, with the legislation driving companies into investment which in turn reduces costs. In many cases the justification would not be there without the motivation of legislation. Integrated MIS (Management Information System) packages developed from SCADA can indicate where and when waste and extra cost is occurring. They can therefore be used to reduce and optimise energy usage.

The cost of utilities can be directly allocated back to the using process and accountable team. In the ideal situation, the cost of utilities supply would be the responsibility of the utilities team, the cost of usage would be the responsibility of the production team. It sounds easy in principal, but having the instrumentation and data collection correctly positioned and configured is a considerable task and very costly. Only the larger modern breweries could justify such a scheme, where utilities budgets run to £1.50/hl which would be £3.0 million for a 2 million hectolitre brewery.

'I don't trust computers!'

With automated systems being more flexible, process changes, improvements and enhancements can be made and tested on site. The old problem of not trusting computers is becoming less common. Blaming the software still happens, but the control system only does what has been programmed to do – nowadays it is normally an instrument or sensor that is faulty, or the programme was not quite right to start with. In a well managed project, a prescribed procedure for developing and installing the software takes much of the pain out of plant commissioning that was such a feature 10 years ago.

Up-front work with customers giving a good process description (URS – User requirement specification) followed by a well developed P & I D (process and instrumentation diagram) and HAZOP (Hazards and Operability Analysis) study gives the control company a sound basis to write an FDS (Functional Design Specification) which is developed into the end software. Testing of the software with the client before it goes to site should give 98% of what is required with only a few minor issues to be sorted at site during actual commissioning. Software simulation packages are available which can fully simulate process plant system inputs and outputs (I/O) via ethernet connection to the PLC software. From experience again, any little awkward decisions that are avoided in the early stages,

will always be there, and are twice as awkward and costly to address on site, so my advice is to leave as little as possible till the last minute.

The Top End ERP and MES

Automation and reporting has been around for a long time using SCADA, but there was always difficulty bridging the information gap between what happened on the plant and what information (and its accuracy) reached the planners and executive management. Inputting data by hand that is readily available electronically in SCADA and numerous other systems was, to those who had to do it, a real 'pain'. In the last few years systems have been developed and improved so that manual double entry is being replaced by electronic transfer in what are called ERP and MES systems. ERP (Enterprise Resource Planning) systems are the top layer, and handle ordering, planning, finance and HR while MES (Manufacturing Execution Systems) provides the electronic bridge to SCADA and the process itself (Fig 9). MES systems basically gather data and analyse it for management control and decision making. It can be said to have three main functions:

1) To provide an electronic paperless system and data flow.
2) Enables key performance indicators (KPIs) to be established and monitored within a brewery, and in large groups, if the data collection systems are comparable, between plants.
3) Recipe management in a controlled environment.

One effect of a properly implemented MES is to force the brewery into rethinking its work processes. Running processes in 'manual' leads in inaccurate reporting, which has an adverse 'knock on' effect over the whole system.

The future

I asked Paul Bunyan and Tony Goodman of FMA about their view of the future trends in IT and automation in breweries. Their view was that large breweries are collecting their 'islands of automation' into plant wide systems, with an emphasis on standards which will ease maintenance and bring consistency to information, which would allow realistic plant and process comparisons to be made. Many breweries have ERP systems like SAP which are separate from production, There will therefore be increased investment in MES systems which will enable electronic transfer of data across the whole operation.

This will improve overall efficiency and cost by reducing order time fulfilment, reducing manufacturing cycle times from ordering materials to shipment of order, improving inventory control, reducing rework from improved quality management. Breweries which have invested in ERP and MES will require and implement higher levels of automation with more rigid standards in order to maximise benefits from these systems; this in turn will lead to a continued reduction of staff, who will be more highly trained. The traditional departmental structure of brewhouse, fermentation, processing and packaging will probably give way to a simple brewing and packaging control structure, although packaging would remain more labour intensive due to the need for more manual intervention.

Those mouse-click Brewmasters

I was talking to a German Brewmaster the other day about 'mouse-click' brewmasters – that is brewers who work in automated plant relying on PLC feed back for all their information. We were in 'grumpy old men mode' and agreed that this new breed of brewer was technologically very competent, but in the real world were not exposed to the sounds, smell and vision of the process, and therefore missed out on having a true feel and understanding of what was happening in their breweries. The 'lights out' philosophy will only exacerbate this and may not be totally desirable. Questions I often ask people if they have problems in a brewery are: what does it look like?, what does it taste like ?, have you felt the pipe to see if it's hot? (there is a health and safety issue here if it's too hot, but then HSE is a whole new ball game!).

'Lights out' operation may be less of a target to some brewery CEOs, but hectolitres per man will remain a key comparator for high level company assessment. In reality I think money is more likely to be invested in reducing the high areas of costs – namely energy, water and waste, and in ERP and MES systems which will improve cost and efficiency, and vital data flow over the whole operation.
'Lights out' is not ideal, maybe keeping a light on in the corner so that the new vigilant operators can still 'walk the plant' and experience and see a bit of what is going on is preferable. In any case who's going to feed the brewery cat – or maybe even that can be outsourced? ■

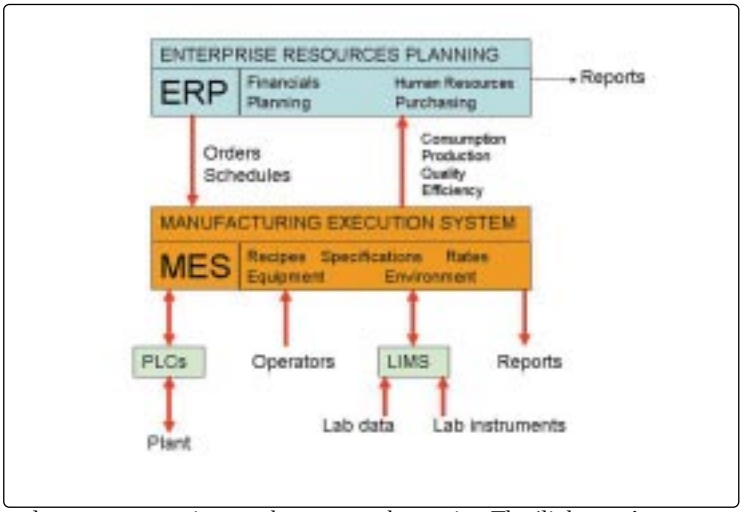


Figure 9: Schematic of modern brewery IT architecture showing ERP, MES linking in with SCADA and brewer PLCs.

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