Expert systems in breweries

VIRTUAL EXPERTS | This article introduces a new software solution, the "Virtual Expert". The products, virtual Filtermanager and Lautermanager, developed by gimbio, have been operating successfully at InBev in Munich (Franziskaner Weißbier, Löwenbräu and Spaten). Average lautering time was shortened by more than ten minutes, while quality and yield were simultaneously improved. Kieselguhr consumption during filtration was reduced by 20 percent, running times were extended by 50 percent.

CONVENTIONAL PROCESS CONTROL rapidly derails due to fluctuating raw material quality, process variations and lack of know-how. An experienced plant operator is required to optimise the process by selecting control parameters or tuning settings.

Information and know-how are of utmost importance in order to produce high-quality products in a safer environment and in order to improve productivity of production processes. On the one hand, this requires suitable process sensors that provide information on the status quo of the process at any given point in time and, on the other hand, a process management system that optimises the process, drawing on process information, extending over the whole range of possibilities.

Modern expert systems provide a unique possibility to observe and characterise process conditions and, based on these, implement process controls. Such expert systems can immediately duplicate the experience and know-how of a highly qualified plant operator. In many cases, the knowledge of a plant operator, accumulated over many years of operation, allows the assessment of process conditions at an early stage and thus enables suitable intervention in case of deviations from standard or ideal conditions. Classical control and automation equipment quickly fails to come to terms with a situation, in particular when dealing with complex processes in breweries where raw materials or intermediate products with widely fluctuating qualities are processed. The inflexible settings in a recipe system are mostly implemented in such a way that they do not take account of qualities, so that such compromise solutions will never yield optimum results. Of course, control systems exist that can compensate for process deviations but they operate with inflexible parameterisation.

Successful control requires situation-based process control where both recipe parameters as well as controller parameterisation are each adapted to the situation at any given time. This is exactly what an experienced plant operator does. He observes the process, assesses the process situation and intervenes manually in order to get to an optimum result.

Up to now, no software solution existed which was in a position to take over the job of a plant operator.

The "Virtual Expert"

The expert system "Virtual Expert" developed by gimbio and the Faculty of Process Analysis and Cereals Technology at the University of Hohenheim is a software solution that takes over the job of a plant operator or assists him in his work. This "virtual plant operator" monitors continuously and simultaneously all process parameters for 24 hours, assesses process conditions and

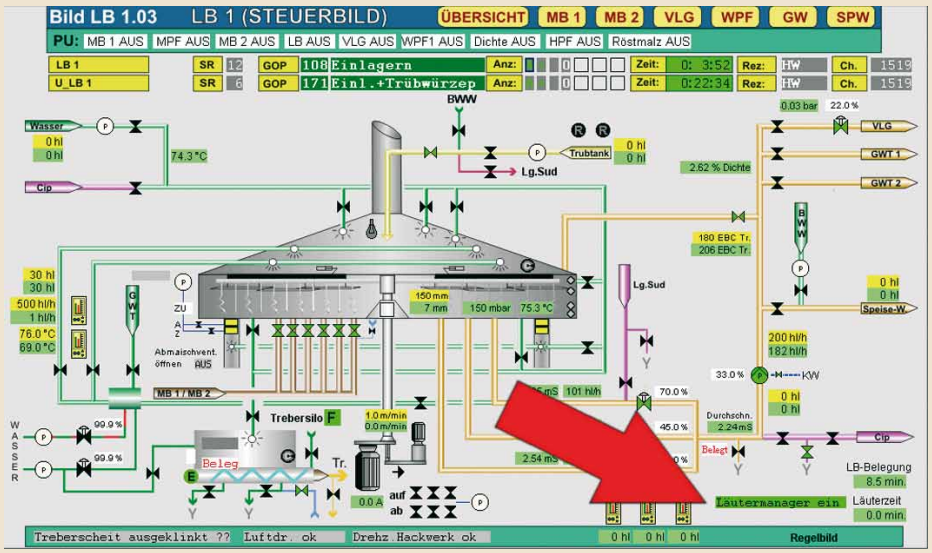

Fig. 1 Spaten-Franziskaner-Bräu GmbH extends the Braumat control of their lauter tuns by adding the virtual Lautermanager (German screenshot)

Authors: Dipl.-Ing. Markus Fellner, gimbio mbH, Adelschlag, Dr. Jörg Lehmann and Harald Wening, InBev Germany, Spaten-Franziskaner-Bräu GmbH, Munich, and Prof. Dr. Thomas Becker, Faculty of Process Analysis, University Hohenheim

intervenes and corrects continuously. It is not a classical control system reacting solely to individual offsets, it optimises the process following prior linguistic assessment of the overall process. It can recognise trends and always reacts in good time. It decides on the basis of expert knowledge and not on the basis of mathematical equations or models.

The Virtual Expert can be combined with almost all systems. It can be simply superimposed on an existing control system. The software is installed on a standard PC, with an interface to the control system.

The Virtual Expert uses this interface and accesses, in reading mode, all information available on the process and, in writing mode, variables that significantly influence the process. Existing sensor equipment is generally sufficient to assess the process situation. Additional instrumentation is usually not necessary but could be easily integrated. The conventional control system remains and can be used as back-up in the case of maintenance or upsets.

The software is integrated during ongoing operation, without stoppages or production shut-downs. It is available ranging from a "turnkey" fully automatic system to a "stripped" software tool, with which every brewery can implement its own ideas after intensive training. In most instances, a basic package with all basic functions is supplied, this is then adapted to the respective plant, as required.

Such expert systems for breweries are currently available for two important production steps: namely lautering and precoat filtration as Lautermanager and Filtermanager. And they are operating successfully. Spaten-Franziskaner-Bräu e.g. has installed both systems, showing the advantages and savings in the brewing process associated with an intelligent situation-based process control.

The Lautermanager

Lautering is frequently the crunch point in production processes in the brewhouse. Widely fluctuating malt qualities in particular, with seasonal variations, supplier and also batch dependant, result in widely variable and, above all, extended process times. Though extensive quality control during receipt of raw materials should ensure uniform malt quality, malt parameters tested will, in most instances, not provide sufficient information about lautering characteristics. In addition, upstream process steps such as milling and mashing can affect the outcome in different ways and are additional risk factors. Predetermined cycle times, quality and yields have to be complied with in order to successfully integrate lautering into the production process.

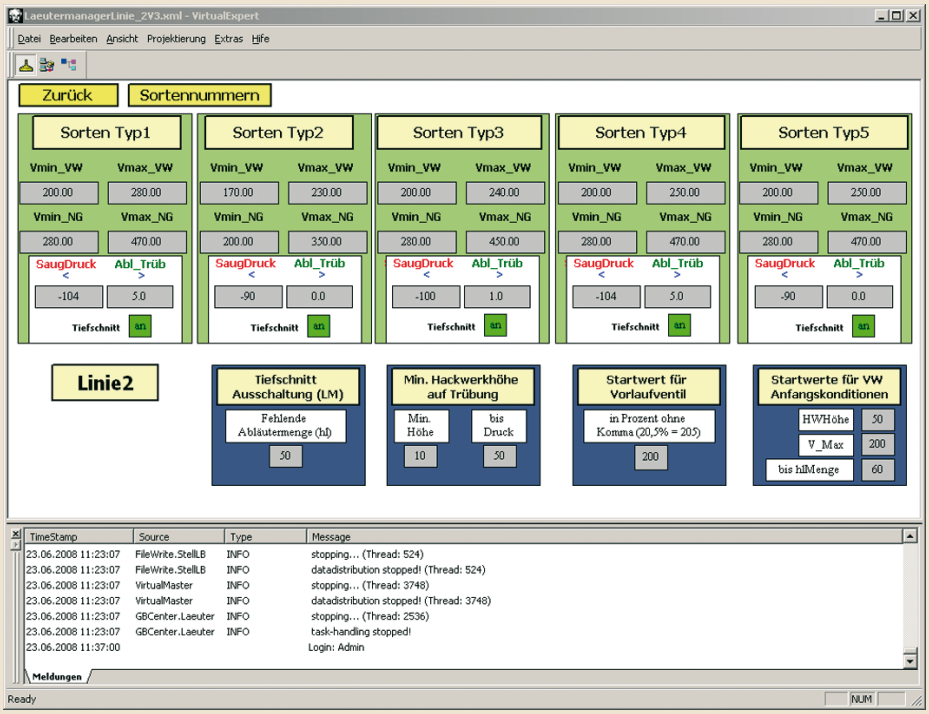

Fig. 2 Individually compiled parameterisation configurations for the brewmaster in the "Virtual Expert" Lautermanager software (German screenshot)

Industrial experience at Spaten-Franziskaner-Bräu GmbH

Upon completion of the pilot project at Bitburger brewery in 2006, the gimbio Lautermanager was also installed at Spaten-Franziskaner-Bräu GmbH in Munich at the beginning of 2007. The project had the objective of shortening lautering times, also when suboptimal malt qualities are processed, such that predetermined cycle times and specified quality requirements could be met.

The existing control system was a classical Braumat recipe control that did not react to fluctuating malt qualities. When lautering characteristics were suboptimal, the plant operator had to adapt the recipe parameters frequently by hand in order to

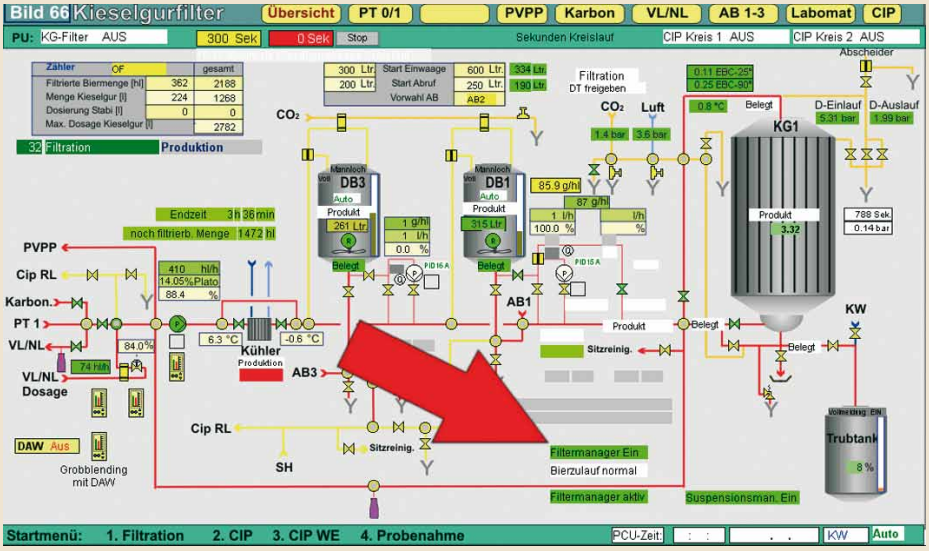

Fig. 3 Filter optimisation by installing the virtual Filtermanager (German screenshot)

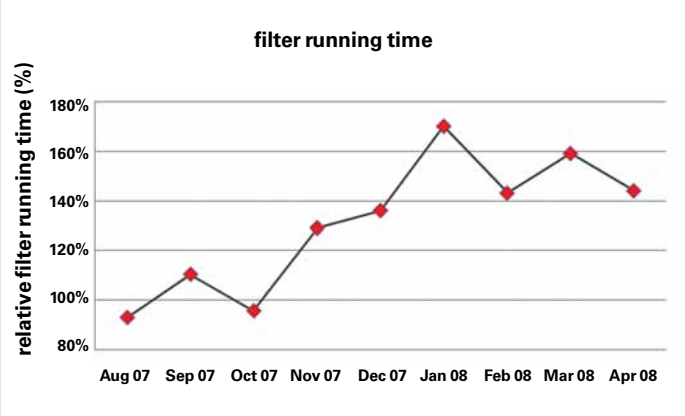

Fig. 4 Development of filter running time compared to the average value in 2007 (commissioning of the Filtermanager from October to December 2007)

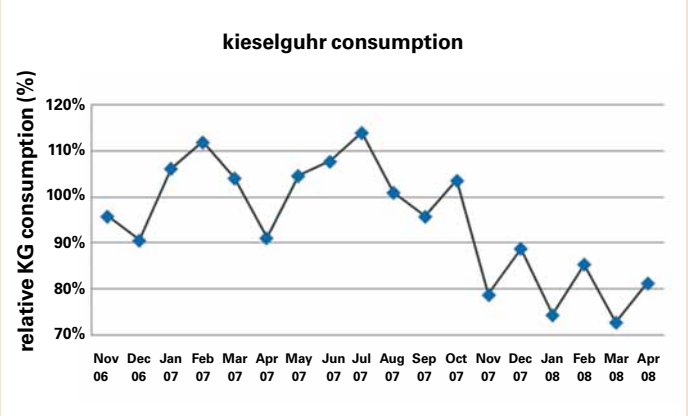

Fig. 5 Progression of kieselguhr consumption compared to the average value in 2006 and 2007 (commissioning of the Filtermanager from October to December 2007)

prevent premature contraction of the spent grains cake. When processing certain beer types, the plant operator was obliged to intervene in the process continuously.

The virtual Lautermanager has been integrated into the system such that it can be activated by the Braumat (fig. 1). The process can also be monitored by the Braumat as before. Once the Lautermanager has been activated, it continually adjusts, as a superimposed system, current parameters for raking unit height and speed, as well as for wort and sparging water volume flow. If required, it calls for deep cuts where suitable and controls pumping of the first runnings. In addition, the brewmaster is in a position to change important parameters such as initial values, throughput limits or deep cut conditions on the screen of the "Virtual Expert", the software platform of the Lautermanager, in order to fine tune the process in line with requirements (fig. 2). The software is so flexible that new conditions and parameters can be integrated at any time. Internally, the Lautermanager assesses the status quo of the spent grains cake changing over time, similar to an experienced plant operator, after an evaluation of the measured values sequence, and decides on adjustment interventions based on its rule-coded empirical knowledge. When a system has been adapted fully, the Lautermanager covers the whole range of process variables arising. Reliable operation is ensured, also in extreme situations. The Lautermanager is designed such that it will automatically implement a time-optimised process operation, while adhering to quality parameters. With good malt batches, the required cycle times are achieved without any problem and the process is optimised in terms of yield and haze. Also with suboptimal qualities, lauter times compared to those of conventional process control are shortened, and the number of manual interventions by plant operators is reduced such that only exceptional cases need attention.

At Spaten-Franziskaner-Bräu GmbH, lauter time could be reduced by, on average, more than ten minutes and the objectives set were achieved. Lautering no longer represents the bottleneck in the brewhouse. Haze and thus wort quality were also significantly improved.

Technological knowledge inclusive

The Lautermanager was developed to provide yet another feature: in addition to time-based optimisation, also in terms of haze and yield, the most comprehensive technological knowledge database possible should be created that can be reliably transferred to other lauter tuns and beer types. It is important to note that only the specific knowledge acquired exclusively by plant operators and brewmasters is used. In this way, the brewery, as such, is in a position to get or regain control and an overview of the critical process. Following a start-up phase with the Lautermanager, process control is completely handed over to the brewery. Without being familiar with complicated programming languages, trained personnel can extend the knowledge base, modify limit values and integrate special features of new beer types. In this way, new ideas and instructions by the brewmaster or process engineer can be implemented rapidly and efficiently and fully transferred "to the beer", without knowledge getting lost.

This strategy differs to that generally applied, i.e. accepting controls as supplied by manufacturers. This established and conventional procedure is paid for with loss of control over the process and can entail follow-on costs when extending or changing over the system. As lautering programmes are generally purchased together with new plants, it is difficult or quite expensive to integrate knowledge that has been subsequently acquired. A brewery has generally the best knowledge about its product and its development over time. When planning long-term, it is advantageous to use and safeguard such knowledge.

The Filtermanager

In the light of positive feedback received from the Lautermanager, such an expert system was also configured for kieselguhr filtration. A pilot project for the "virtual Filtermanager" started at Spaten-Franziskaner-Bräu GmbH in October 2007 and exceeded the envisaged saving potential already at the beginning of 2008. A candle filter supplied by Filtrox (fig. 5), with a nominal throughput of 600 hl/h, required optimisation. It had to cope with a filterability that changed from one beer type to the next, from one batch to the next, mainly on account of the heterogeneous storage situation in the brewery. Like the brewhouse, the filter cellar is equipped with a Braumat recipe control and is operated by filtering staff working in several shifts. The filtering staff decide on selection and dosing of a suitable kieselguhr suspension and set the throughput rate. They also make proposals for adapting the filtration schedule to suit the filter condition at any given time. As the filter is very sensitive, filtering staff must have sufficient experience and, when making decisions, take account

of information passed on by previous shifts. Running times and kieselguhr consumption are thus not only a function of beer quality but also depend on the experience of plant operators.

The project at Spaten-Franziskaner-Bräu GmbH had the following objectives: reduction of kieselguhr consumption, extension of the filter running time, standardisation of beer quality, as well as avoiding critical conditions and freeing personnel from routine jobs. The Filtermanager is based on the software platform "VirtualExpert" and has also been designed to be superimposed on the existing Braumat recipe control. It can access all measured values in the filter section and can call up the filtration schedule. Within certain modules, it can intervene in the filtration process.

The filter control module continuously adapts throughput rate and kieselguhr dosage to suit filtration characteristics at any given time. The suspension manager determines time, kieselguhr mixing ratio and quantities of a kieselguhr suspension to suit the situation at any given time. In doing so, it also takes account of the residual quantity from the filtration schedule and the estimated remaining time determined by the third module, the Filtration Estimator. This estimates the remaining filtration run and point in time when the process is due to be stopped, i.e. reaching maximum pressure or maximum kieselguhr quantity. This is of help to the Scheduler.

The fourth module, the so-called "type memory", analyses filtration history of individual beer types and gives instructions about selection of the first suspension after the first and second precoat or in the case of an imminent type switch-over.

The plant is provided with a fully automatic kieselguhr mixing station. Without increasing the workload of staff, the batch size of the kieselguhr suspension prepared could thus be significantly reduced and a higher response speed to changes in filtration runs was achieved, especially ahead of a type change. By providing a uniform basis for decisions about the selection of a suspension, the integrated expert knowledge, of itself, has a very positive impact on the overall result. Residual kieselguhr quantities at the end of filtration, unsuitable for subsequent filtrations, were largely eliminated by the system. A better result can thus be achieved, also on plants without fully automatic kieselguhr preparation, by giving specific instructions to staff.

In the pilot project, process control optimised in that way resulted in considerable savings (fig. 4, 5). In addition, staff were freed from routine jobs to a considerable extent. Kieselguhr consumption was reduced by 20 percent, filtration batches were increased by 30 percent and running times were extended by 50 percent. Better haze values were achieved on average. This made a considerable contribution to standardising beer quality. As the number of cleaning and precoat cycles was reduced, water, CO_2 and energy consumption, as well as the amount of kieselguhr sludge, could be minimised.

In both projects, the processes of lautering and filtration were optimised. In addition, upstream production steps could also be newly assessed. ■