IMPROVED INTEGRATION OF ENTERPRISE AND CONTROL LEVEL WITH COMBINING ISA BATCH STANDARDS AND PROCESS MODELS

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Abstract

Optimization of the batch operation was and still is an important issue in many batch plants. The S88.01 standard, published by the International Society for Measurement and Control (ISA) in 1995, providing standard models and terminology for the design and operation of batch control systems at the process-cell level, has been supporting many automation projects. The new S95 standard of ISA, published in 2000, helps in the direction of integrated plant optimization. It is aimed at modeling integration of business systems like ERP with control systems like DCS and SCADA. However, it is remarkable that very little attention is paid to the improvement of recipes and process management for industries acting within a dynamic technological and turbulent market environment. None of the MES (Manufacturing Execution Systems) functions described by the batch standards endorses the possible advantages of using formal process models for optimizing a master recipe, next for adjusting it during processing as a control recipe, and further for improving scheduling activities. In the paper an industrial need is recognized for the extension of the existing MES approaches with a model-based operation improvement module, which easily can communicate with other modules. The example describing model-based optimization of a crystallization plant illustrates the integration of scheduling and process management. The implementation in the plant of the developed operator advisory-system needs integration with other MES modules. This task would be much easier when MES systems, working according to the batch standards, recognize a call for a module for model-based operation improvement.

Keywords

Batch processing, modeling, integrated plant optimization, automation projects, ISA batch standards S88 and S95

Introduction

In the last few decades, developments in the global economic structure have changed the environment in which process industries operate, enforcing them to cope with:

- more short-term dynamics in supply and end-product markets as well as more unpredictable and turbulent demand patterns
- shorter series of manufactured products
- stricter requirements on product quality
- a shift from specification products to performance products
- greater emphasis on shorter and more reliable production time
- an increasing number of product grades and brands
- a need for improved customer service.

These challenges enhance the complexity of manufacturing operations, and create a need for enhanced flexibility. Many process industries choose for the flexible batch-wise mode of operation in response to these challenges. Batch-wise production of higher added-value specialities is a fast growing segment of the process industry (i.e. food & beverages, chemical, pharmaceutical, metal industry etc.) in most industrialized countries. However, the flexibility of a batch plant poses the difficult problem of the allocation of available equipment for producing a dynamic mix of desired products and setting up a production plan to decide if, when, and in what amounts, products should be produced. Moreover, the dynamic character of processing steps, which do not operate in a steady-state mode, complicates further the operation and control of a batch plant.

To stay profitable in the dynamic technological and turbulent market environment, a suitable strategy is needed to ensure market competitiveness and high productivity. It is a well-known fact that the short-term planning, scheduling and control function have a large economic impact on the performance of an industrial plant. The production is dynamic with an ever-changing mix of actual products in production. Operation and scheduling should be flexible in such a way that actual operation may change by new entries of orders. Lifetime of production plans may become shorter and might be adapted at operational level.

Optimization of the batch operation

In the recent years, batch process optimization has made significant advances. The S88.01 standard, published by the International Society for Measurement and Control, provided standard models and terminology for the design and operation of batch control systems has been supporting many automation projects (ISA, 1995).

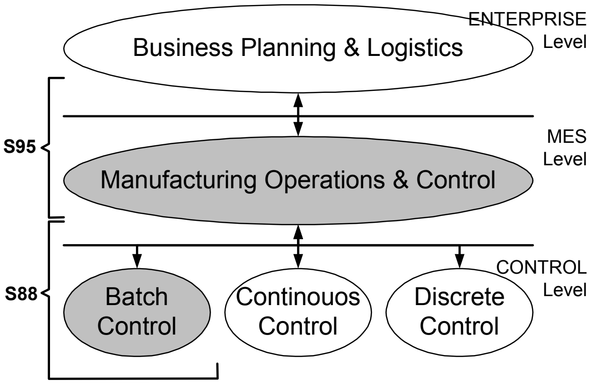

Figure 1 Scope of the S95 and S88 standards related to the scope of this article (grey areas)

However, the recipe model describing master and control recipe and the structure of the control concepts according to the S88 standard refers only to the process-cell level and therefore supports optimization of an individual process, see Figure 1. This is not enough in today's very competitive business world. The challenge for control engineers is to focus on wider aspects of site optimization, (Ghosh, 2000). The new S95 standard of ISA, helps in the direction of integrated plant optimization (ISA, 2000). It is aimed at modeling integration of business systems like ERP with control systems like DCS and SCADA by describing the contents and interaction of MES (Manufacturing Execution System) functions:

1. Resource Allocation and Status
2. Operations/Details Scheduling
3. Dispatching Production Units
4. Document Control
5. Data Collection/Acquisition
6. Labour Management
7. Quality Management
8. Process Management
9. Maintenance Management
10. Product Tracking and Genealogy
11. Performance Analysis

However, it is remarkable that very little attention is paid to the improvement of recipes and process management for industries acting within a dynamic technological and turbulent market environment. A suitable strategy uses formal process models for optimizing a master schedule or recipe, next for adjusting it during processing as a control recipe.

Model-based operation improvement

To support model-based operation improvement at the process cell level a so-called flexible-recipe improvement approach can be recommended (Verwater, 1998). Table 1 shows the activity domains of this approach.

The process model developed at the process cell level allows for an almost instantaneous optimization in the utilization of the master recipe due to e.g. economic changes without process remodeling. However, taking decisions with respect to recipe correction should take into account not only the consequences at the process level but also the consequences for the coming scheduled processes. Adaptation of the process model according the recipe initialization and correction makes a production system adaptable to a changing market environment. Integration of scheduling and control becomes essential. The recipe adaptation set can form the basis for the integration of scheduling and processing activities.

An industrial call for an approach supporting optimization at various system levels, varying from process cell level, area, site to whole enterprise could be answered by introducing the twelfth module "Model-based Operation Improvement" to the before mentioned MES functions. Its contents depend, in the same manner as for other functions, on the plant needs, data availability and already developed process models for the plant.

Table 1. Scope of the flexible-recipe approach

1. Development of a recipe adaptation set (*RAS*) and recipe improvement	2. Application of a recipe adaptation set for an adjustment of a control recipe
Aim: Improvement of a master recipe with the aid of a recipe adaptation set. Recipe adaptation set contains a process model, process constraints, performance criterion (objective) and the master recipe itself.	*Aim:* Batch initialization (compensation for deviation known at the start of the batch) Batch correction (compensation for the deviations occurring during processing)
Master recipe provides specific information how a product is to be produced (ISA, 1995)	*Control recipe* contains detailed information for minute-to-minute operation of a single batch (ISA, 1995)

Integration of scheduling and process management as presented by Figure 2 forms the basis for this.

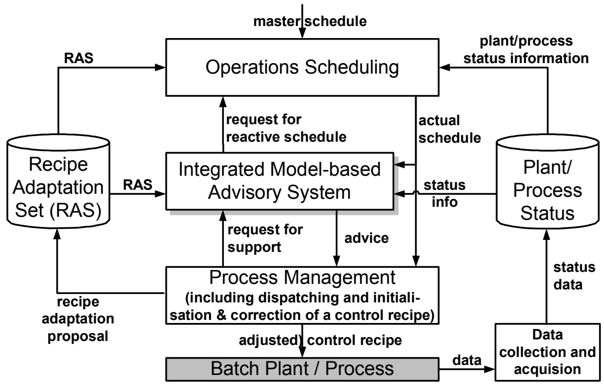

Figure 2 Model-based operation improvement by integration of scheduling and process management

Case study - model-based operation improvement of a crystallisation plant

Figure 3 shows a simplified model of a crystallisation plant. Main production units are a number of A-pans (van Wissen *et al.,* 2002). Input for these A-pans is new feedstock, mixed with the output products of the B-pan. The B-pan has an upgrade function for the resulting product. Second input for the A and B-pans is from the preparation (P-pans). Inputs for the P-pans are derived from the mixed input and the output streams of the A pans. Typical batch times in the pans are hours and response times on operator actions are long (hours). There is a limited capacity of steam available and maximum and minimum buffer levels are critical. The maximum level is derived from the buffer capacity, the minimum level is defined to prevent time consuming cleaning operations when buffers should become empty and flows would stop. Pans have a changing steam demand during batch operation. This simplified model already shows the complexity of the process.

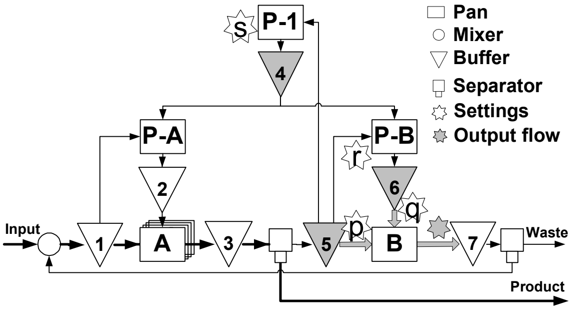

Figure 3 Model of the crystallisation plant

Operators are able to set the starting times of the pans (discrete events) and the quantity of the flows. They act in response to actual flow and level changes and expectations, according to their own mental plant model, about future behaviour of flows and levels. Process management of the plant is aimed to assure product quality and optimal process operation. Product quality is subjectively judged by operators for colour and taste and objectively measured at the granular distribution. The analysis of the granular distribution takes about twenty minutes. For optimal process operation the output flow of the B-pan (grey star in the figure) should be without extreme fluctuations, the buffer levels (especially buffer 4, 5 and 6) should be within their level boundaries. The cumulative energy (steam) demand of the pans should be as constant as possible. Steam is generated in another part of the plant and is assumed to be constant.

Two objectives for the operational improvement are central. The first objective was to reduce the fluctuations in the energy system and steam supply for the pans. The second one was to predict a regular product quality. The complexity of the process leaded to a model-based optimisation project.

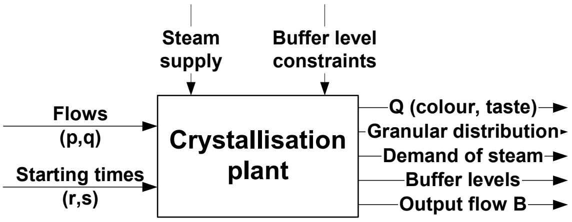

Figure 4 A part of RAS, concerning process model and constraints, of the crystallisation plant

Figure 4 shows the crystallisation plant as a black box. The operator settings as the flows (p, q), starting times (r, s) are at the left (see also Figure 3, the constraints (steam supply, buffer level constraints) at the top and the results (product quality and process optimisation) at the right. The availability of a plant model will improve the operation by advising the operator about starting times of the pans and settings of the flows. The model uses a time horizon of more than a shift period and a single model replaces the different mental models of shifts or operators.

The information generated by the RAS is used in a model-based advisory system, which helps the operator in making decisions; i.e. the operator-support system is able to predict the consequence of an action taken by an operator with respect to the scheduling questions (the system can deal with a what-if scenario).

For this an existing mass-balance model of the plant has been extended with energy balances, recycles and variable cycle times for batch units. It is a hybrid model, consisting of batch and continuous pans and intermediate storage buffers. The product flows and volumes are calculated in mass components: water, product, waste and crystal. This leads to a model with approximately 25-30 variables (e.g. levels, flows, program counters and dry substance content).

The key part of the model-based advisory system is Model Predictive Control (MPC). MPC is a control technique that calculates a sequence of control signals in such a way that it minimises a cost function over a prediction horizon. The widespread use of MPC in chemical industries is because it has several nice features: MPC can be used for handling multivariable and/or constrained problems and its concepts are easy to understand for operators with only a limited knowledge of control (Bordons, 2000).

In Figure 5 the actual plant situation without the MPC support is compared with a situation with MPC.

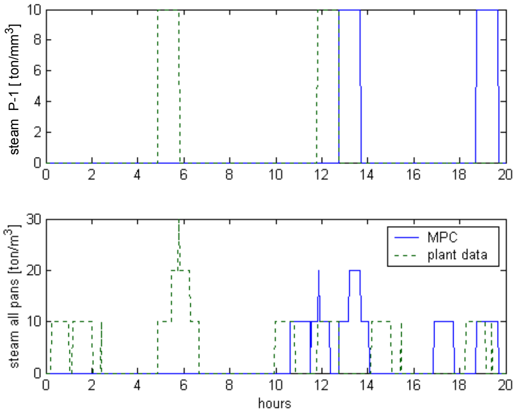

Figure 5. The MPC algorithm clearly affects the demand of steam. A penalty has been set on violating 10 ton/m^3 steam. Note the violation in the second plot at about 6 hours (30 ton/m^3 steam) for the plant data.

The results show a significant reduction in fluctuations and heat peaks in the heat demand. Hence, an increased on-spec time with tighter specs is realised, too. But, more importantly, a much more stable process-operation is achieved within a time-horizon of about 10 hours. The results are promising and the implementation in the plant will start very soon.

Final remarks

The implementation of the developed conceptual advisory system in the plant needs integration with the existing modules for Data Collection and Acquisition, Process Management and Operations Scheduling. This task would be much easier when MES systems, working according to the batch standards, recognise a call for a module for model-based operation improvement.

To conclude, it should be mentioned that three separate batch worlds are active. Firstly, the industry operating batch wise. Secondly, software suppliers focussing on the integration of data streams, mainly for preparation and evaluation of operation. Thirdly, research groups are developing advanced dedicated models and methods. Integration of these worlds may also provide invaluable support for integrated site-wide optimisation.

Acknowledgement

The research described in this paper is part of the multi-disciplinary project "Batch processes – cleaner and more efficient" carried out at the Delft University of Technology in co-operation with five batch processing companies and TNO TPD Delft. In one of the companies involved the presented case study was performed. The Dutch Ministry of Economic Affairs and the Ministry of Education, Culture and Science financially support the project in the framework of the E.E.T. program (Ecology, Economy and Technology). The authors gratefully acknowledge the financial support and the scientific cooperation with parties involved in the project.

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