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Experience on Advanced Process Control in Chemical Industry

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Abstract

The reasons for advanced process control (APC) being attractive in chemical industry are discussed. It is concluded that the APC benefits can be derived from the properties of the chemical processes and processing options. Process interaction examples of multivariable nature are elaborated and reduced to a few fundamental recognizable driving forces. The mainstream APC technology types are reviewed. The role of dynamic simulation is highlighted and APC implementation features are discussed. An example with project characteristics and milestones is given. The multivariable advanced control of an atmospheric crude unit, specializing to produce solvents with strict quality requirements in Fortum Naantali Refinery Finland is described. The recipe-driven model predictive controls (MPC) with frequent operating mode changes are discussed. The experience of the control application and achieved results, after three years of operation, are discussed. The experience of the factors helping to retain the APC functionality after closing the project and the importance of good organizing, training, service and support is discussed. Suggestions for future work opportunities within fertilizer industry are presented. It can be concluded that implementing APC continues to be rewarding and the current trend for increasingly higher product quality specifications will in our view only emphasize the importance of APC in the future.

Process and APC Economy

The advanced process control (APC) has been well established for more than twenty years in chemical industry, particularly in refineries and petrochemical processes. However, the current trend for increasingly higher product quality demand and narrowing economic margins has still emphasized the importance of APC and caused a number of APC application types hitherto regarded as uneconomical to become attractive. In our view, there is a clear need to reassess the current economic values for APC application candidates for profitable implementation in chemical industry.

An essential feature of many chemical processes is an inherent flexibility, which permits them to be run at different process conditions and using different feedstocks to produce specification products. In addition, many products may be mixed from components originating from different operating conditions and/or process units. This inherent flexibility in making the final products provides in most cases the fundamental basis for the existence of processing options necessary to exploit the APC potential in chemical plants. The more complex the plant the more options there are as a rule. Without such options there are practically no opportunities for improving the processing economy with any APC applications.

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In many cases the improved product property uniformity resulting from APC allows higher customer prices or provides better fidelity and therefore is to be considered through customer network interaction analysis.
A factor, which for certain processes may have a value vastly exceeding all the preceding benefits, is the improved safety, reliability or environmental pollutant control, due to APC.

Benefit examples

There is a number of APC success stories in the professional papers. Good candidates are applications, with complex processes, like chemical plants, refinery processes, ethylene plants, polymer plants, ammonia plants etc. Typical payback times range from 4 months to 2 years, mainly depending on the needed process change and analyzer investment costs. An Ethylene Plant for example was able to increase ethylene production by 2-3 per cent (depending on the feedstock) due to APC and gain much more precise quality control on products. A polymer plant gained 2 per cent onspec production increase and an ether plant was able to increase throughput by more than 3 per cent. A refinery with two atmospheric crude units was able to increase the total production value through quality control to gain 1.7 year's payback time.
The clearest and most important contributors to economic benefits are pushing onspec production rate and/or production value.

Production rate

Regardless, whether we consider the whole chemical plant or a process unit of it, increasing throughput generally means more production. To maximally utilize the available equipment (device) capacities is the most easily recognized source of improvements from APC applications.
Increasing feed rate and, hence, production rate beyond average manual operating performance (often beyond design capacity limit) is fortunately made possible by APC's ability to approach closer each individual capacity constraint in real time. It is well known that the "unit capacity" changes in real time depending on the interactions between unit devices and process conditions. It generally turns out, that one of the unit devices, e.g. the feed pump, will first reach its maximum capacity when feed rate is increased, but for the other devices there is still unused capacity available. If, for the sake of argument, the back-pressure of the pump would be decreased, the feed rate to the unit could be increased beyond the previous "capacity" until some other device, e.g. an air-cooler, would reach its capacity limit. On a cool or rainy day the air-cooler would not be the limitation and the feed rate could be even further increased until the next device would reach its limit.
The air cooler is an example of varying capacity limitations, which can't be influenced. The control strategy here is to exploit an opportunity by *riding* the constraint whenever possible. Above, the example of decreasing the backpressure is an example of "buying" capacity by an active move, at the cost of reduced downstream pressure. This is an example of *balancing* constraints to approach maximum production rate by moving not only the feed rate but also relaxing a constraint by moving another variable. This example serves to remind that an efficient pushing controller generally moves several more variables than just the feed rate.
A throughput-maximizing controller has as the main vehicle the ability to measure a large number of potential capacity limiting constraints and to adjust the feed rate in such a way that always the currently most limiting constraint is approached. The interactions between

the controller variables will determine to what extent it is feasible for the controller to “buy” more capacity. In real applications the interactions between essential process variables need of course to be simultaneously considered.

Generally more accurate control means less safety margin need and this together with the feed-pushing control gives substantial (often 1...5 %) increases in the throughput for many process units and, hence, for the whole plant.

Production Value

Many plants produce simultaneously or sequentially several products, which have different prices. Within the constraints of product specifications and the varying unit capacities it is in principle possible to determine the set of operating moves, which gives the highest value of the sum of products minus plant feedstocks and operating costs at any point in time.

For conversion units, for example, the production value can readily be adjusted by selection of reaction conditions, like reactor temperature for instance.

Likewise, every distillation (multi-product or simple) column presents opportunities to maximize the production value by manipulating the yield(s) and separation. Increasing a product yield makes the product less pure. Furthermore, all other products in the column are affected by the material balance and become either less pure or more pure through interaction. As a simplification, the operative task in this context can, therefore, be visualized as maximizing the yield of the most valuable products against their specification limits. The vehicle for this task is clearly a properly formulated product property control APC.

Also in this case, when the specification limit has been reached, more production can be “bought” from improved separation at the cost of energy. The increased separation reduces the overlap or impurities for adjacent products, which can then be exploited to increase the yield of the most valuable products at the expense of the less valuable ones. Particularly in this case a multivariable optimizing controller becomes necessary to handle the whole unit.

The product quality violation at quality control has penalties of varying strength depending on how difficult it is to rectify the violation effect to the final product as compared to the monetary loss from equal quality giveaway. This function is invariably more or less nonlinear. This type of asymmetric control will generally result in a small (optimal) margin of the average to the quality specification, while only few spikes reach the specification limit.

For plants with frequent feed/product changes the transition product minimization is of importance too and may justify grade change control applications. A particularly attractive situation is a case where the transition product can’t be downgraded to the previous or the next product in the processing sequence, as e.g. in producing solvents or polymers.

Overview of Advanced Process Control

Advanced process control encompasses a very large number of recognizable different technologies. In this paper we focus on the real-time advanced process control (APC) technology applications on continuous processes only, without regard to the supporting technologies for plant information management, manufacturing execution systems, planning, scheduling, etc.

Advanced Controllers

The backbone of an APC application is model-based predictive multivariable controller (MPC) technology. The use of MPC’s is frequent in petrochemical industry and the status of the technology must be regarded as both mature and well established. Different formulations of MPC problems differ particularly in the robustness and fault-tolerance aspects, which is of course of high importance for the implementation and long-term applicability to different processes.

Process Models

Different kinds of process models have long been in use to provide reliable estimates for important process quantities, which are either immeasurable or difficult to measure. These quantities can be used as feedback, constraint and disturbance variables for typical MPC’s and for controller adaptation. The models, which produce these quantities are of several types, ranging from deterministic dynamic models and online models to correlation models, heuristics, neural networks, expert and fuzzy systems. Deterministic models have proved the most reliable, applicable and transportable in general, even if a number of well-established neural net applications have become popular.

Recipe Systems

Many chemical plants operate using widely different raw materials to different process units. In addition, block mode operation (sequential processing) is common, where the product (or products) is adjusted to accommodate the changed feed composition or to satisfy the market cycle. This creates a need to safely operate at vastly different process conditions and to make quick transitions between these modes of operation. The process models, which generally speaking support these transitions, have to be of dynamic and non-overall-equilibrium type. Also the database framework to support reliable operation in each of these regimes has to recognize and support the case-sensitive nature of the application. The integration of the above functions is referred to as Recipe System in this paper.

Process Stream Analyzers

Many modern process stream analyzers, like X-ray fluorescence/diffraction, NIR, NMR, GC and MS are very complex modeling systems themselves and provide much useful information of the process stream composition besides the principal measured quantities. Multi-stream analyzers in particular may also possess nasty properties like low sampling frequency and substantial dead time. In processes, where the time constants are small compared with the dead time for example, the controller needs special functions and fault-insensitive model structures. The maximal utilization of analyzer information and screening of measurement errors provides profitable opportunities. Ensuring reliable analyzer information has a profound impact on the success of any APC implementation, which (even partially) is dependent on analyzer information.

Realtime Operations Platform

Although there is a large number of data collecting information systems, only a few platforms also support safeguarded APC connectivity directly and make the implementing easy. Reliability and availability of the integrated functionality of a full application is of course the most important feature of the final system, but the engineering tools and the transparency of the platform are decisive for the cost of the implementation.

Use of Process Simulators in APC

Purpose

Simulation is typically used for four partly overlapping reasons. The first reason is to try to understand the underlying process and to see how it can be operated. This mode of simulation is mainly aimed at studying a process in

- normal operating situations
- feed composition changes
- disturbance and upset situations
- catalyst exchange and maintenance
- startup and shutdown operations.

The second reason for using simulation is to support development of control systems. Here the main topics of study are:

- testing the controllers
- tuning controllers, in order to get a picture of what can be achieved
- using the model for generating response data to be used for controller design, at least for part of the targets
- comparing different controller configurations
- evaluating the functioning of the control system in the different situations outlined above
- doing precommissioning of control systems, especially for advanced controllers.

The third reason for simulation is to look at safety aspects of the process with its control system. Typical uses are:

- testing the effects of malfunctions
- trying to find ways to handle the process in severe disturbance situations
- estimating the flare loads in emergency situations, e.g. after loss of cooling water.

The fourth reason is operator training. Here it can be noted that the complexity of the model usually is quite high since it usually also contains a copy of the DCS environment in which the operator works.

Process Models

The models used in conjunction with APCs are of different type depending on the application where they are used. The models used within MPCs need to be simple enough in order to allow efficient computation of the control moves. They are often identified from process experiments or alternatively linearized or simplified from rigorous physico-chemical models. Immediate benefits can be obtained by using rigorous models for generating part of the models (or model responses) used in the APCs, thus shortening the time needed for process experiments.

Rigorous models for supporting APC design and testing are usually based on material- and energy- balances for all involved units. In these equations chemical components and phases are modeled according to the best available physical and chemical property data. The balance equations are enhanced with vapor-liquid equilibrium correlation and reaction rate expressions. These kinetic equations are chosen and tuned according to the available process data. Further, flow and pressure-drop calculations as well as operational characteristics of critical equipment are included. In many cases the models are configured so that there are basic controllers for e.g. flow, pressure, level, and temperature. Depending on the needed scope of the model and the simulations, simplifications can be made in items of marginal interest from a control point of view.

Implementation of APC

There are several ways to implement APC applications, ranging from in-house development to turnkey delivery. Typically, at least the APC technology and tools but very often the total application is provided by an APC vendor.

To get started

In chemical industry maximizing the production rate, safety, running time and quality while minimizing the raw material usage, energy consumption and emissions are targets for all production personnel. In some cases there are clear solutions for enhancing the process performance using advanced process control tools, but certain restrictions may cause that no project will be started – despite the fact that the idea is good and profits would be substantial.

On the other hand, there are also some pitfalls during an implementation that should be avoided by proper action in the preplanning phase. In the following some common and perhaps most important items are presented, which should be settled before starting an APC project. As a minimum the project cost should be evaluated.

Existence of analyzers or instruments

The specific field instruments or analyzers required for the control application may not be readily available. In chemical industry the circumstances are often very challenging and difficult, and standard instruments on the market do not necessarily fulfil the reliability requirement set by automatic control applications. Problems are often encountered with chemical analyzes of fluids and in particular with solids. Laboratory analyses are often too infrequent and sometimes informative only.

Sometimes even ordinary level, pH and flow measurements are hard to arrange (like in reactors). The feasibility and sensitivity of the implementation has to be verified in face of these possible uncertainties and the possibility of process model use to be assessed.

Ensure field-proven tools

Sometimes an innovative project staff may be eager to use only the latest technical tools for solving the engineering or control application problems (simulation tools, special control packages e.g. fuzzy control). In case the staff doesn’t have first hand experience in using these tools, the choice may prove counterproductive and may even ruin the economy and time schedule of the project. It is therefore advisable to use tools, which have already been tested in at least pilot projects and proven to be practical for the intended purpose.

Commitment of the Production staff

APC projects are not only for control engineers! It is very important that members of the operating personnel are nominated to the project group. Production engineers can help to specify the targets and limitations and also supply the necessary knowledge in processes and chemistry needed in the project. By participating tightly in the project the production staff is highly committed also when the project is over.

Control Scope

When planning and evaluating an APC project, the team may turn so excited, that too many unproven items may be judged feasible within the scope of the project. Too big a scope is equally dangerous than a too limited one. In our experience there may be several control problems in the same project, but each of them should be finite enough. It is evident for instance that taking blindly all the inputs from a process to an APC block and trying to get optimized control moves and sending them to the process will have remote chances to succeed. The key is to first understand the internal process interactions and then to produce controls supporting these interactions by proceeding piece by piece.

Human Interface

In our experience the main target is to keep the interface for the operator as simple as possible. There may be a very complicated application behind the interface, but the interface must be easy to operate and to understand. The targets of the control, as well as the constraints, status and alarming have to be indicated clearly to the operator. The service factor is frequently closely related to panel operators' view of the usefulness of the control. A high percentage of time in manual-mode is an indication of either poorly designed controls, poor measurement availability or poorly conducted operator training and support. In particular if the interface is too complicated, the operator may not truly understand or agree with the control. In our experience, operators design the best interfaces themselves.

Organizing training for new APC applications needs to be arranged very carefully, with the full support of the production personnel so that all the shifts get the same training and information.

APC implementing, a long-span work

The resources too often leave the project too early – watch for this! Control implementation and fine-tuning demands in some cases very long-span work and although this is generally not work-intensive at lest long time availability of the key specialists is needed. Process circumstances vary – different production rates, producing different grades etc. - and all special situations have to be reviewed. It is important to reserve resources for a sufficiently long period.

Service and Support

The process itself may frequently change or be altered with time, and these changes have to be incorporated to the control applications too. It is important for the plant personnel to have the skills to understand the implications of process changes to the controls and to carry through the necessary updates by their own (trained!) resources or through APC provider.

Organizing post-project work is important, otherwise the designed control applications may have a tendency to deteriorate and in worst case may be in manual-mode after the project staff has left the project.

We would like to stress, that all the pitfalls mentioned above can be avoided. This can be done by good preparation of the APC project, reserving time and resources and taking care that production staff is also committed to the project. One must be also realistic when evaluating the costs and benefits of the project – the investment needs to be profitable. It has turned out in several projects, that additional benefits materialized from sources, which were not anticipated in the evaluation stage.

APC implementation example

We feel, that one real implementation example is more illustrative than elaborating several alternatives.
Fortum Naantali Refinery APC application is described as an example of implementation due to a number of interesting challenges.

Naantali Refinery is of a complex refinery type with hydrodearomatization technology. Its automotive and fuel products comply even with the Californian specs. Refinery product slate includes gasoline, diesel, fuel oil, LPG and the specialty products like solvents, aviation and other specialty gasoline products, specialty oils, bitumen, etc.
Two parallel atmospheric crude units are employed to produce from varying crude oils different product slates.
Currently the DCS employed is Valmet XD and the APC platform is ABB PMS-NT built on a Compac Alpha AXP process computer network. NAPCON multivariable adaptive control technology from Neste Engineering Oy was installed throughout the refinery. Several new on-line analyzers were installed for process control and quality control reasons.

MPC Project

Although Neste Engineering Oy was in charge of the MPC project, a joint project group with representatives from Naantali refinery was founded to facilitate the technology transfer. This decision proved one of the most decisive success factors. Also our concept to maximally utilize the dynamic process model for home office work proved successful in substantially saving time and money.

The main APC project milestones were:
- Kick-off meeting
- Project schedule and procedures defined
- Process dynamic model generation
- DCS and process upgrade
- Analyzers
- Operator interface design
- APC control engineering
- APC functional test runs on dynamic simulator model
- Detail documentation
- Project group training
- DCS reconfiguring and tuning

- Process model and APC installation
- Operations Documents and Procedures
- Operator hands-on training
- Control commissioning
- Control performance tests
- Project acceptance and closing
- Post-project service

In the control design phase Neste Engineering dynamic simulation system PROSimulator was extensively used. The rigorous non-linear physico-chemical models of the crude units were generated and used to simulate the process and to export the models to the controller. The desired configuration and tuning of the MPC could be carried through four months earlier than if a full identification using plant data would have been done. Process tests were minimized to a few verification tests and very little interference with operations resulted. Particular attention was paid to analyzer fault/error diagnosis. The analyzer signal conditioning of the MPC technology enables detection and avoiding the consequences of analyzer failures.

After the commissioning there has been no need to change the tuning parameters of the commissioned controllers. The few additions made after the project are due to new products introduced by the refinery in the course of time. The trained personnel of the refinery have completed these add-ons.

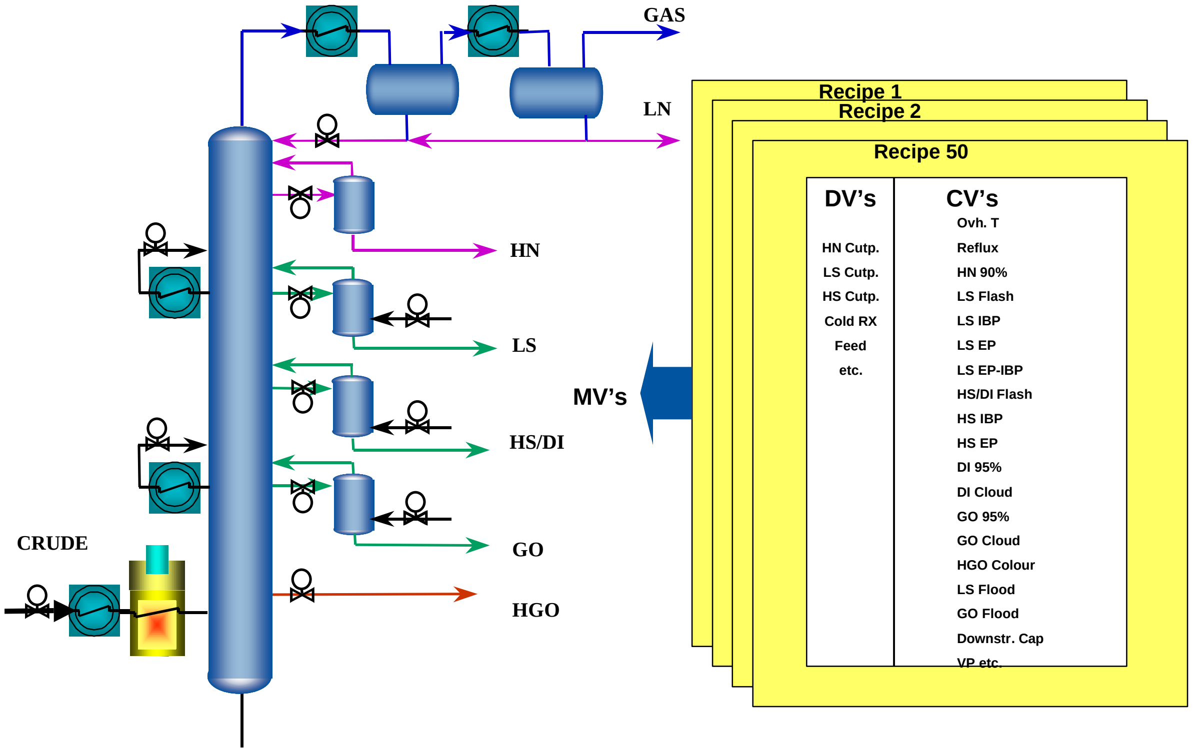
Control Objectives

One MPC including product quality controls, feed maximization control and on-line grade change controls is configured for each unit.

In the following only one Crude Unit MPC (Figure 1) is described as an example of the implementation.

The objective is to maximize the value of the onspec production of the products against product property specifications and process constraints by manipulating product yields, reflux, feed rate, pumparounds and stripping steams within the feasible operating window.

Figure 1: Naantali Refinery Crude Unit APC scheme



Control Strategy

Twelve product properties of the crude unit are controlled to their targets or specification limits. Particularly important are flash point, cloud point and distillation. The sensitivity of the initial boiling point (IBP) and end point (EP) for the solvent products is even more pronounced than the corresponding 10 and 90% points used for regular oil products. Because typically two adjacent solvent products are drawn from the middle of the column, the control of initial and final boiling points becomes an essential part of the multivariable product quality control. Most property controls are nonlinear and asymmetric. This type of control ensures that critical quality property specs are not violated, because a barrier function is used. In the property control the model-based predictions are necessary, since most of the analyzers have a cycle time between 15 min and one hour.

Disturbance variables include both ordinary and estimated types. The control technology permits incorporating also internal (implied) cascade controls based on external process model results.

Feed maximization controls adjust the feed rate (and other variables) until the predictions of the constraints start to approach their limits. These consist of column flooding and downstream unit capacity constraints. The approach to flood is predicted using column process model with mass and energy balances and V/L equilibrium relations. The crude unit MPC incorporates 21 process constraints to safeguard staying in the feasible operating window of the crude unit.

The solvent produced during grade transitions does not fulfil the product specifications of any of the several solvent products, and has to be minimized. The grade change request activates the recipe transition and controller reconfiguration will automatically follow online, using the targets and specifications of the new product slate.

Benefits

The crude unit controls have been in continuous use for three years from the commissioning except for short process upset and turnaround interruptions.

The product quality controls have been able to efficiently and selectively use the on-line analyzer results. The technology has also been well able to cope with the analyzer failures, without loss of quality control.

Operator acceptance has been high, most likely due to the fact that panel operators themselves designed the operator interface displays as a specific part of their tasks in the project group.

The reduction in the product quality variance has enabled the controller to increase the production of the most valuable products at the expense of the least valuable products and is operating the unit closer to the specification and process constraints. After commissioning of the MPC, the standard deviation of solvent and diesel product properties have dropped to less than half in average. Diesel cloud point variation, in specific, dropped to one fifth. The grade change times have reduced the offspec production by up to 50 percent.

The payback time for the automation capital investment project is due to better production management and reduced offspec production. The project payback time covering the capital expenditure of the process computer network, the process information system, the 11 installed analyzer systems and the crude unit controls is about 1.7 years.

Control use experience

The benefits from an APC will continue to accumulate only if the application is in continuous use. Continuous service factor surveillance has proved a key factor in maintaining high service factors

APC training

It has unfortunately proved that neglecting training and servicing controllers and the devices they are depending on will tend to cause gradual deterioration of control performance in general.

It has been our practice to install on most APC applications also a training environment, where a complete copy of the MPC and a corresponding simulator are included on the same platform as normally used by operators. These have been used for operator training during the project and after the commissioning when new panel operators have been appointed. Particularly where operator rotation is practiced, scheduled recapping can be fruitful.

Service

A controller can do only as well the actuators and measurements allow. Generally the DCS controllers have to be kept as much in good shape as the APC. As an APC manipulates DCS controller setpoints it expects a quick and stable response. In fact, the acting DCS controller response is included in the internal process model of the MPC.

The service statistics show clearly that a vast majority of DCS controller performance deterioration cases is caused by valve of measurement problems.

Regular instrument service has proved completely sufficient to support APC applications, provided that an up-to-date documentation and training is provided. What has proved useful is the set of service displays on operator interface. These displays contain instructions for servicing instruments having a connection to the APC application and a description of the influence on APC. Instrument technicians can check and agree with panel operator of the safe and correct procedure steps to avoid interfering with the APC application.

Support

Modern plants are far from static in configuration and in operation. Process changes are done and new products launched.

Obviously APC applications have to be upgraded to match with the changes, which generally calls for re-engineering the APC application. In many cases the local staff has acquired the skills needed to carry through the modifications, which again underlines the importance of training in APC projects. This time, however, the training in how to use the tools of building MPC.

Future Applications of APC in Fertilizer Processes

Control of sieving and granulation

Granulation is one of the most difficult processes in the production of solid fertilizers. A typical granulation process is shown in Fig. 2 below.

The granulator and drier produce spherical fertilizer granules with a size distribution from 0.1 mm to 10 mm. The granules are elevated to a multi-layer sieving system, which separates the product size granules, typically 2 to 4 mm. The oversized granules are crushed and then returned with the undersized fraction to the granulator.

Important factors affecting the operation of the granulator – sieving system are:

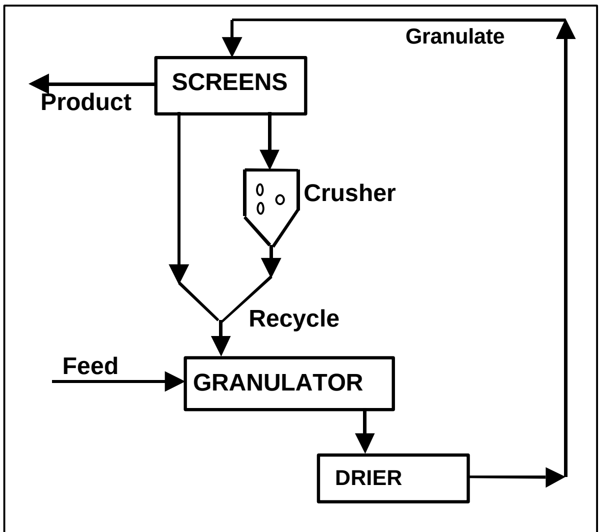


Fig. 2 Granulation

- properties of the slurry (Feed), incl. viscosity, density, surface tension spraying in the drying drum, condition of the nozzles, air pressure
- size distribution in the recycle flow
- rotation speed of the granulator
- vibration amplitudes and frequencies of the sieves
- cleanness and condition of the sieve nets

Several projects have been carried out in Kemira to develop a control system for the granulator-drier subsystem and the total system.

The next step within Kemira will be to start with modeling the sieving subsystem in order to develop a condition monitoring software, which indicates and alarms, whenever the sieving system does not perform within set tolerance limits. After that, control of the granulation – drying system using a combination of model based and fuzzy control techniques will be further developed.

The main goals for the granulation control system are:
- increased throughput
- savings in energy
- optimal product size distribution

An essential means of developing the advanced control of granulation is the on-line analyzer for granule size distribution, which has been developed by Kemira Engineering Oy, a daughter company of Kemira.

pH control

In a fertilizer process, pH is an important variable both in the reaction stages, and the outlet gas washing units. In the reaction stages, a specific problem is the physical properties of the slurry, which requires specific sample handling facilities for obtaining an on line measuring system. Both in reaction stages and in gas washing units the control is complicated by the

variation in the chemical composition of the slurries due to different product grades and raw materials. These cause essential changes in the shape of the titration curve. Also, because of limitations set by the product recipe, the pH controlling agents vary, occasionally even two different acids are used simultaneously for the control.
Good results have been obtained with a pilot application of a self-organizing control algorithm for a gas-washing unit. Adoption of the same principle to other gas-washing units as well as to the most difficult reactor controls is foreseen.

Control of product analysis

The long time constants and lags found in the fertilizer process make it possible to control the chemical composition of the product even manually fairly well, when there is a reliable instrument for analyzing the product. However, the flexibility of the production units tends to increase the number of grade changes per week, emphasizing the importance of obtaining the correct product analysis in minimum time after each grade change. Also, in a multi-product plant, the off-spec product is collected and recycled, causing a source of disturbance in the process. Some raw materials used contain several nutrients, which means that a change in the raw material's relative proportion affects several product analysis components.

So far, satisfactory results have been obtained by using a recipe control model off-line, but the increasing number of grade changes per unit time already seems to justify initiating a development project for closed loop analysis control.

Further applications

In addition to the three development areas described above, the following new applications are under consideration:

- Utilizing a fertilizer pilot plant for developing new process analyzers and control methods

The pilot fertilizer plant of Kemira Agro is currently rebuilt and will be provided with the most up-to-date process instrumentation including the on line analyzers developed by Kemira, as well as a modern digital control system with an advanced information management system. This provides excellent possibilities for control system development with substantially lower costs and lesser risks for disturbing the production during experimentation.

- Optimization of the automatic grade change

One of the first applications of digital process control in Kemira was the automatic grade change in NPK plant (around 1984). In the first stage, the automation was based on empirically found time profiles for each raw material feed rate, when changing from grade A to grade B. When the on line product analyzer was developed and taken into use, these profiles could be refined using the registered results of past grade changes.

The next step was to develop an off line dynamic model of the reactor – granulation system for simulating the process with alternative raw material profiles. This was developed in late 80ies and has been used quite intensively. The system, however, requires that the user creates the profiles and adjusts them according to the results.

The next logical step is to develop the system further so that it also creates the most efficient feed profiles. This is not a simple task, because the system must also be taught, which intermediate conditions are feasible, i.e. not to run the process into potentially dangerous conditions or conditions, where the physical properties of the intermediate stages cause e.g. jamming of the slurry.

The pilot fertilizer plant may prove to be a good resource in advancing with the optimization of the grade change. The economical gains from such an application would be very attractive.

Conclusions

Advanced process control is to day an approved means for increasing the profitability of many, even complicated chemical and petrochemical processes. APC includes a diverse set of tools from which the best-suited ones can be selected for each application.

A factor often limiting the adoption of APC is the lack of know-how within the production company. However, consulting services in the field are available both from system suppliers and control engineering companies to help with the control system engineering and guide in the introduction of the technology. The process know-how of the production company and the involvement of the production personnel are of utmost importance in achieving a practicable solution.

Carrying out an APC project most often brings other benefits through the improved understanding of the process and its internal interactions. These other benefits may even surpass the original expectations for the APC.