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Industry 4.0 for batch cooking process in Mondi Stambolijski

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Abstract

Batch digester technology for pulp delignification is one of the oldest processes in the pulp and paper industry. The connection of discontinuous and continuous production is burdened with an extremely long inertia of cooking process. Regular sequencing suffers under disorders of connected continual processes and vice versa efficiency decreasing effect in turbine house due to the fast changes in the steam flow towards digester house.

The industry 4.0 opens quiet new approach to control of this complex of conflicting requirements. Digitalization of batch cooking process (virtual digester house as a mathematical copy of physical, technical and technological properties and functions of the real plant) enables forecasting of the steam flow more than 1 hour ahead. The forecasting software is synchronized with interval of 1 minute in order to continuously clarify trend of steam consumption 60 minutes forwards. This information simplifies control task in turbine house, which significantly increases efficiency of power production.

At the beginning of each heating sequence the digester specific heat parameters are automatically calculated using available instrumentation and digester heating recipe is maintained significantly precise compared to the former temperature control. The steam consumption is smoothed, which again simplifies control task in turbine house.

The most decisive task for mill data communication is a balancing of production rate between paper machine and digester house. This function controls digester sequencing as a superior function including pulp storages and its availability in connection with production plan on Paper machine. The purposeful usage of pulp storages reduces inefficient time in digester house to minimum and maximizes production capacity of the paper machine.

Limits of classical optimizing methods

The absolute majority of control loops in pulp and paper industry is realised by classical PID controller and a huge part of them are configured as PI only. Moreover, the information carrier among separate control loops is material flux. Because of relatively long dwelling time and high process inertia, the stabilising of defined operational conditions is a serious problem.

The relationship between production, quality and effectiveness because of strong interactive effects is so complex, that an optimum can rarely be reached by simple tuning alone. The investigation of these relationships by individual system trials has limited success rate, is expensive and anyhow approaches the simple method of “Trial and Error". This costs time, energy, quality and production. An absolute majority of already “classically” optimized systems often operate below their technical and technological limits. Very often these limits are even not known.

It is not enough to optimise control of a separate department in the production lines without regard for the current production conditions of surrounding departments. A non-harmonised production speed in the particular departments is causing loss of production capacity and growth of energy specific consumption.

Installed instrumentation in a plant gives valuable process information used for immediate control. In the next second 99% of this information is lost. But the information flow can be used significantly more efficiently! Industry 4.0 shows the way how the digitalization of process flow intensifies usage of installed instrumentation equipment to reduce process costs and improve process stability.

Digitalisation of technological process

Mondi Stambolijski EAD, part of the international packaging and paper producer Mondi, together with CF Procsim GmbH and AutomationX GmbH opened the door for Industry 4.0 at its mill in Bulgaria. Virtual technology and intensification of data usage at production departments and theirs transfer between departments is the basis for industry 4.0. The starting point was assembling of virtual process for digester house. In order to predict energy and mass flows for one hour ahead the virtual plant was connected online to the real one. This enables frequent synchronising and robust process simulation in virtual future. The predictive functions of virtual digester house stabilise steam flow, digester sequencing and coordinate production balance between digester house and paper machine.

Virtual digester house is a mathematical copy of physical, technical and technological properties and functions of the real plant. It reacts on input signals in the very same way as the real one. Because all processes are described with help of physical variables, equations and sequences, it is easy to derive any significant process value. The user interface to the virtual digester house is identical to the real process. Therefore the results of "operator" handling is simple to observe, tune or even modify or develop new control functions.

This tool was effectively used to test and tune predictive functions in order to stabilise process flows. Predictive functions as a core of virtual digester house connected online to the process control steam flow to digester house, maintain the heating recipe significantly more precisely compared to former temperature control. The steam consumption is smoothed, which simplifies control task in turbine house. The digester sequencing is synchronised in order to regularly maintain pulp production target and simultaneously equalize mass and energy flows from supporting departments.

As a first step of digitalisation a deep investigation of current plant areas has been performed. Recipes, measurements, procedures and routines were analysed on stability and accuracy. Mass and energy balance system covering the whole digester house has been developed to investigate sustainability and accuracy of measured process variables from historical database. Results were used to derive dependent process variables and simulate or even displace expensive measurements like e.g. wood moisture. The individual digester parameters have been specified based on this investigation, as well.

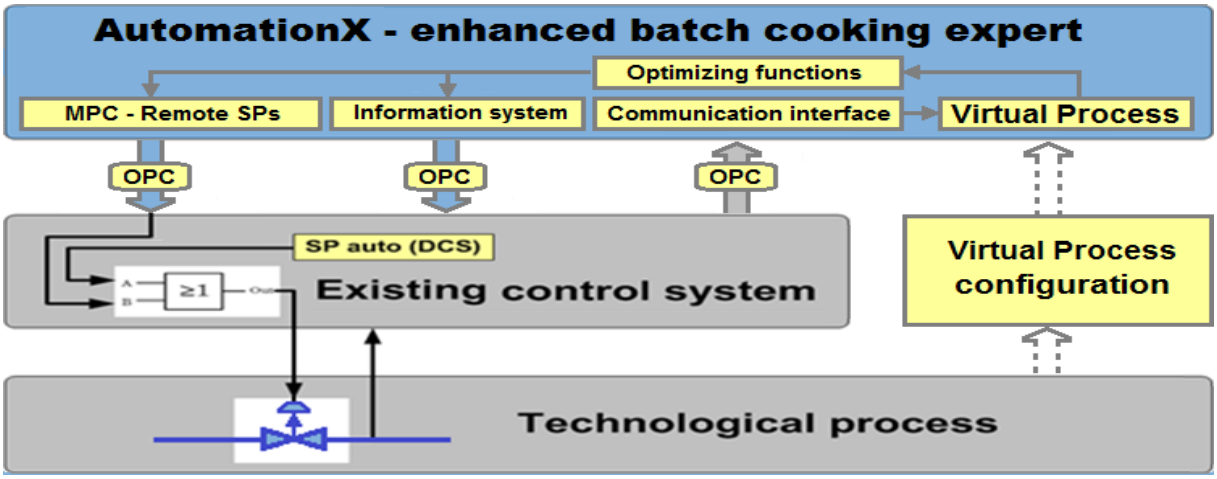
Prediction of steam consumption

A completely new function of digester house control systems is the prediction of steam consumption. The steam consumption depends strongly on the digester phase and has rarely the highest priority in the plant. Therefore the batch process is always disturbing factor for steam network. A robust and reliable value predicting steam consumption several minutes ahead is an excellent information for feedforward control in the control system of steam turbine.

The virtual cooking house is regularly synchronized with the real plant and simulates the process sequences with all active digesters one hour forward in the minute cycle. The mean duration time of sequences is continually calculated using data from the last several days for each digester separately, whereby the bigger disturbances and irregularity are excluded.

This feature (self-learning routines) ensures high precision of steam consumption curve and an exact time of bigger steam flow changes independent on weather and season. This online predictive function is unique in the pulp industry and supports a secure control of steam production and increases the efficiency of the steam turbine.

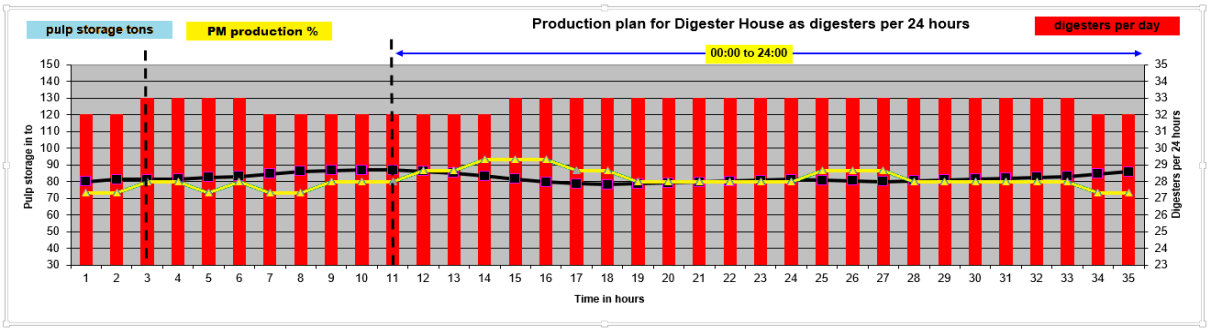
Figure 1. Principal online connection of virtual digester house to the existing control system. Virtual process obtains data from real plant, synchronizes state of all virtual digesters and starts simulation according to the defined end time. The simulation results are saved in the file and over OPC transported to the existing control system. This process starts every minute. The configuration of virtual digester house can be online changes (adapted) in any time.



Harmonization of production speed among individual departments

The most critical task for mill data communication is a balancing of production rate between paper machine and digester house. This is a crucial issue to reduce energy consumption and to maximise usage of mill production capacities. This coordination was done verbally only and there was no standard in form of defined procedure. That's why the potential for improvement was remarkable. The harmonising function controls digester sequencing as superior function including pulp storages and its availability in connection with production plan on paper machine. The purposeful usage of pulp storages reduces inefficient time in digester house to minimum and maximizes production capacity of the paper machine.

Figure 2. Production plan for the next 24 hours of cooking (red bars as number of cooking per day in the particular time) is calculated according to the evaluation of stored pulp before PM (blue line) and PM production plan (yellow line). It ensures enough space for pulp from the digester in the case of the break and enough pulp for PM in the case of sequence disturbance in the digester house.



Conclusion and results

The project has been successfully implemented in six months. Due to the thoroughly positive project results the remaining production departments could be simulated and connected together into the **virtual mill**. The process data from surrounding departments could be used in virtual ones in order to optimize set points in virtual future and send them back to the real process as remote set points. This

approach harmonizes available production capacities decreasing specific energy costs. The equalizing of production rate in all departments supports automatically quality control and maximizes usage of mill production capacities.

The project acceptance and project support by mill operating staff were exceptionally strong. This was also a solid bases to meet together all project objectives:

- Due to new steam flow control (comparing former temperature control) the fluctuation in steam consumption was reduced by 30%.
- The maximum change in the steam consumption in one minute (as limiting value defined by turbine house) was even undershot by 20%.
- The variation of the Kappa value was reduced by 15%. In the used kappa target this reduction brings yield increase (at the range of lower kappa) up to 1.4%.
- The prediction of steam consumption for the 60 minutes forwards has greatly improved stabilization in the steam network.
- The harmonizing of production speed in the digester house according to the tank storage and production plan on PM improved stability and equilibrium of digester house production plan, increased significantly operator's information level and gave his handling more assurance.
- The interface to offline version is very similar to the DCS operating station and the virtual cooking can therefore be used as a training tool for newcomers, or for testing of new functions and procedures.