The use of an adaptive model-based predictive controller in the control of a Kamyr digester simulation

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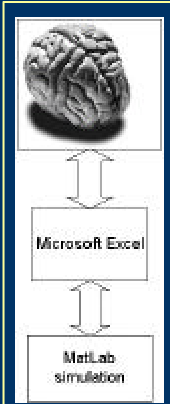
Introduction:

The control of a Matlab-based Kamyr digester simulation has been investigated using a commercially-available model-based adaptive-predictive controller. This controller, BrainWave, can be used for both single loop and multivariable processes. The control of the simulator has been performed using Dynamics Data Exchange (DDE) protocol for communications between the simulator and the controller. The adaptive feature of the model-based controller allows it to accurately learn the dynamics of the process, leading to tighter control of the desired control set points. The use of measurable upstream process disturbances (feedforwards) greatly assists in improved control.

Methodology:



The BrainWave controller and the Matlab simulation communicate via DDE using an Excel spreadsheet, since this allows both BrainWave and Matlab to interact with cell values. At the end of each calculation cycle of the simulator, the data is outputted to the spreadsheet, and the BrainWave controller interacts with this data to calculate the next control move. Since the calculation time of the simulator is not constant, the simulation is paused until a predefined time interval has been reached before it outputs its process variables. This approach is necessary since the BrainWave controller operates at a fixed update interval.

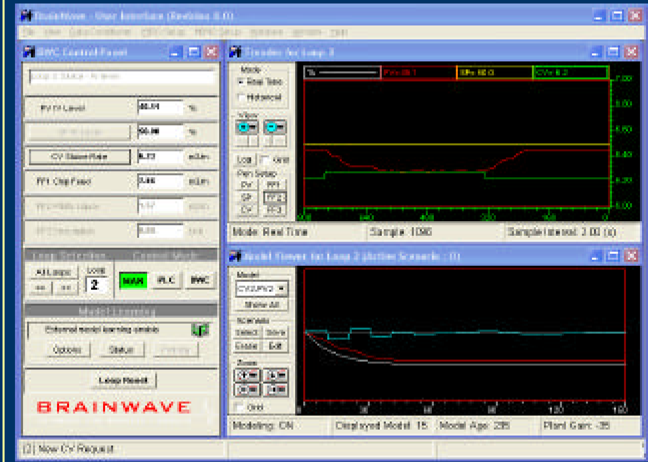
The simulation allows the user to interact with all process variables associated with the operation of the digester. For the purposes of this example, the BrainWave controller is configured to control two loops. The controller can also use measurable disturbances for improved process control, and where possible these are utilized. The first loop of the controller is simply trending the chip feed and production rate of the digester. The remaining loops of the controller are:

Loop 2: Control of Impregnation Vessel level using sluice as a controlling parameter, in addition to using Chip Feed as a measurable disturbance.

Loop 3: Control of Digester Vessel level using blow flow as a controlling parameter, in addition to using sluice as a measurable upstream feedforward

Additional loops may be configured as the simulation demands, with the controller able to operate up to 32 single loops simultaneously. A multivariable version of the controller, MultiMax, will be used in future since this should improve control of the simulator owing to the unique interactions between the various process parameters.

Results:



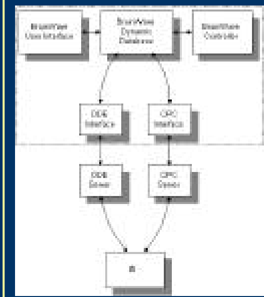
The figure shows a screenshot of the BrainWave User Interface whilst the controller is learning the process dynamics of the IV level during manual mode sluice rate changes. The Trender window displays a real-time chart of the operating conditions of the simulation, and from this it can be seen that a positive change to the sluice rate (green line) causes a negative effect in the IV level (red line). The Model Viewer window displays how the controller is adapting the initial control model (white line) to the exact process model (red line). The blue line represents the Laguerre network coefficients that the controller is using to model the process.

This loop is configured to have chip feed as a feedforward, and the same process of model estimation and manual mode model adaptation is utilized to determine an exact match between the controller and the actual process dynamics.

BRAINWAVE

THINKING THE PROCESS THROUGH

Predictive Control Strategy:



The BrainWave controller consists of a number of modules. At the heard of the system, a database controls the flow of information. Communications with external devices can be performed either by using OPC or by DDE protocols. The BrainWave User Interface allows the user to configure all aspects of control performance, and the calculations are carried out by the BrainWave Controller module. The modules themselves talk to each other using TCP/IP, allowing them to run on different computers.

The controller uses a set of orthonormal Laguerre functions to model the process. These functions can be used to model first and second order process responses accurately, as well as processes which are dead time dominant, a common feature of large industrial processes.

The configuration of the controller uses straightforward process parameters, namely dead time, time constant and gain. The advantage of this approach is that the user can perform a simple step test to determine these control parameters. In contrast, PID controllers require abstract tuning parameters for good performance which are not easily determined from typical process operation.

BrainWave additionally can control both self regulating and integrating type process responses. In the case of the Kamyr digester simulation, it was found that control of the impregnation vessel was best performed using the self regulating control algorithm, whilst tight control of the digester vessel was found to require the integrating controller.

Conclusions:

It has been found that the control of a Kamyr digester simulation is possible using a commercially available model-based adaptive-predictive controller, BrainWave. Control is enhanced by the use of adaptive modeling, which learns the exact process dynamics as well as through the use of measurable upstream feedforward parameters.

Both self regulating and integrating controllers have been used for control of the impregnation vessel level and the digester vessel level. Measurable feedforward signals, namely chip feed for the IV level loop and the sluice rate for the digester level loop have been found to enhance the controller performance.

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