ADVANCED PREDICTIVE ADAPTIVE CONTROL OF STEAM HEADER PRESSURE, SAVEALL CONSISTENCY, AND REEL BRIGHTNESS IN A TMP NEWSPRINT MILL

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ABSTRACT

This paper describes the application of an advanced predictive-adaptive process controller on main steam header pressure, saveall consistency, and paper brightness control at a TMP paper mill. The improved control of the main header pressure virtually eliminated the venting of steam during upsets of the refiners or the paper machine. Improved consistency control from the saveall to the blend chest contributed to stable stock consistency for the paper machine. The advanced controller was able to provide closed loop control of the paper brightness at the reel by adjusting the addition rate of bleach in the bleach plant. The paper brightness was previously controlled manually due to the long delay time between changing the compensated brightness set point in the bleach plant and the observed change in paper brightness at the reel. Each of these applications demonstrates the advantages that paper makers can achieve with advanced regulatory process control.

INTRODUCTION

This paper describes the application of an advanced predictive-adaptive controller (AC) at a TMP mill. The predictive control capability enables significant performance improvements compared to conventional PID loop controllers. The advanced controller models the system response using a function series approximation technique based on Laguerre polynomials. It is able to control processes with long delay or response times or fast response processes where the time delay is a significant part of the response dynamics. This modeling technique can be used to automatically include the effects of measured disturbances as feed forward variables. The following sections describe the Laguerre modeling method and the steam header pressure, saveall consistency, and reel brightness control applications and results.

ADVANCED CONTROLLER DEVELOPMENT

The first step in designing a model-based predictive adaptive controller is to build a mathematical representation of the process response, or model, for the system to be controlled. This adaptive controller uses a new method of process transfer function modeling developed at the University of British Columbia by Dr. Guy Dumont and Dr. Chris Zervos [1-6]. This method reduces the effort required to obtain accurate process model as it is able to automatically build a transfer function model using a series of orthonormal Laguerre functions. The Laguerre function series is defined as:

$$l_i(t) = \sqrt{2p}\,\frac{e^{pt}}{(i-1)!}\,\frac{d^{\,i-1}}{dt^{\,i-1}}\left[t^{\,i-1}e^{-2pt}\right] \qquad \textbf{(1)}$$

where: i = 1 to N
p = Laguerre Pole
t = time

Summing each function in the series with an appropriate coefficient or weighting factor can approximate a process transfer function:

$$g(t) = \sum_{i=0}^{i=\infty} c_i l_i(t) \qquad \textbf{(2)}$$

where: $g(t)$ = Process transfer function
c = i^{th} Laguerre coefficient

An analogy would be the use of Cosine functions in the Fourier series method to approximate periodic signals. In this case, weights for each Cosine function in the series are determined such that when the weighted Cosine functions are summed, a reasonable approximation of the original signal is obtained.

In process control, the process transfer functions are transient in nature and are not periodic, so Cosine functions are not an appropriate choice as a basis for the model. The Laguerre functions are well suited to modeling the types of transient signals found in process control because they have similar behavior to the processes being modeled. In addition, the Laguerre functions are able to efficiently model the dead time in the process response. This model is used as a basis for the design of the predictive adaptive regulatory controller using a simple d-steps ahead predictive control law to forecast process response so that set point is attained as rapidly as possible with little or no overshoot. The advanced controller was installed on a PC under Windows NT. The controller is interfaced to the existing DCS using an OLE for Process Control (OPC) server. Logic was programmed in the DCS to determine the mode for the control loops (i.e., manual, PID Auto, or Computer Auto). The controller maintains a heartbeat with the DCS such that the DCS will automatically fall back to PID control in the event of a fault.

STEAM HEADER PRESSURE CONTROL

The problem with the existing steam header pressure control is the pressure transients that occur during major upsets to the plant such as the loss of a refiner (major steam source) or during a sheet break on the paper machine. The transients would often result in an over-pressure condition on the header and the venting of steam to atmosphere or significant under pressure to the mill systems. A steam accumulator is used to help avoid the under pressure condition as the mill power boiler is unable to respond fast enough to pick up the load when a refiner trips. Refer to Fig. 1 for a simplified schematic of the pressure control system. The advanced controller was installed on the main header pressure control loop (PIC-0460) and the steam accumulator pressure control loop (PIC-0420). The set point for PIC-0420 was set slightly lower than PIC-0460 so that the accumulator would only provide steam when the main header pressure could not be maintained.

A performance comparison for main steam header pressure control under normal operation is shown in Fig. 2. The advanced controller variance from set point was about 89% lower than that for the PID controller. In addition, the improved control has virtually eliminated the venting of steam during major upsets resulting in an estimated annual savings of about $50,000 USD.

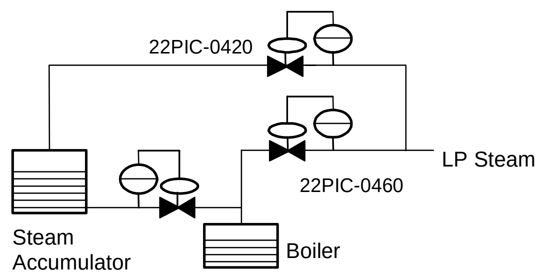

Figure 1. Steam Header Pressure Control Schematic

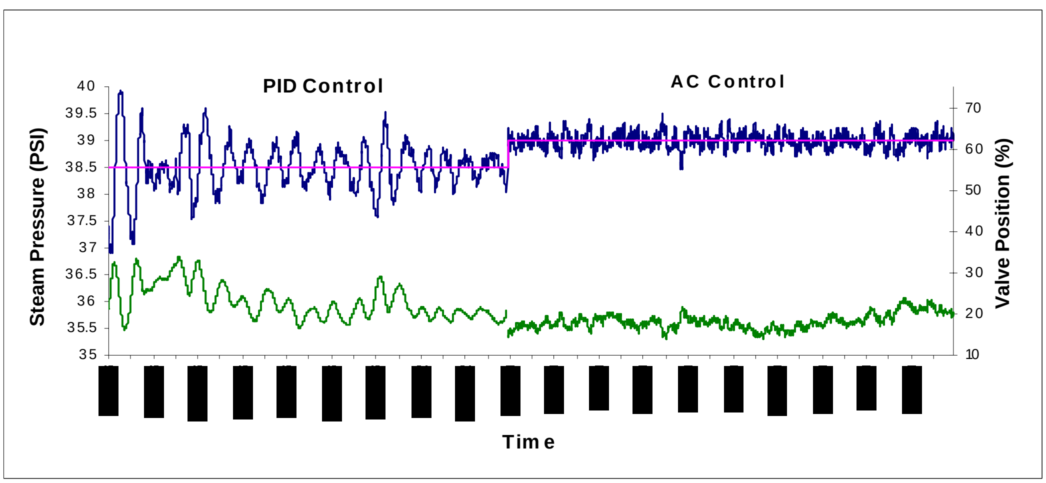

Figure 2. Steam Header Pressure Control Comparison

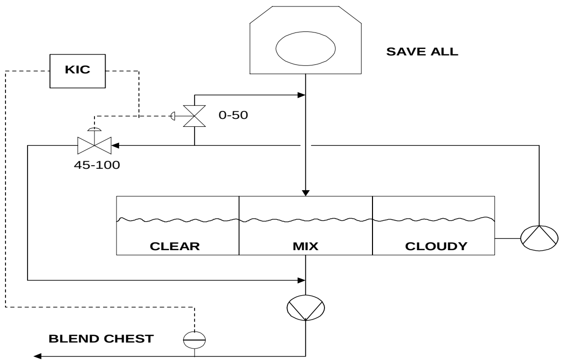

Figure 3. Consistency Control Schematic

SAVEALL CONSISTENCY CONTROL

Saveall consistency control is difficult due to the wide range of variability of feedstock available from the saveall. Regulating the flow of white water that is mixed with the stock before it is pumped to the blend chest controls the consistency of the stock recovered from the saveall. A simplified process schematic is shown in Fig. 3. During normal operation the dilution is added to the stock and mixed in the saveall mix chest. A second valve that operates on a split range from the consistency controller provides dilution at the suction of the saveall mix chest pump during major process upsets when additional dilution is required. The mill prefers to add the dilution on the feed into the saveall mix chest as the chest provides additional capacity to minimize the effects of consistency disturbances. The response dynamics of this loop include a 300-second dead time and a 900-second time constant. These dynamics made it difficult for the mill to tune the existing PID controller to achieve good disturbance rejection performance.

It is important to maintain stable consistency in the stock being supplied to the blend chest as disturbances in consistency can propagate to the paper machine and effect basis weight control and paper quality. The advanced controller was able to model the response dynamics and provide improved control performance compared to the exiting PID control scheme. A chart of consistency control performance is shown in Fig. 4 for a five-hour period of operation for each controller. The advanced controller was able to reduce the consistency variability by over 86% compared to the existing PID controller.

PAPER BRIGHTNESS CONTROL

Paper brightness is an important quality parameter for paper customers. The pulp is bleached with sodium hydra sulfite in the bleach plant to ensure that the final brightness of the paper at the reel is within the customer’s specifications. For many paper makers, the last point in the process where brightness can be corrected with bleach is quite far upstream from the reel. For this mill, the response time for a change in bleach to be seen at the reel was about 3 hours. This long response time makes it difficult to achieve closed loop control based directly on reel brightness. A simplified schematic of the brightness control system is shown in Fig. 5. This mill used a manual or “open loop” control scheme where the operator would monitor brightness at the reel and

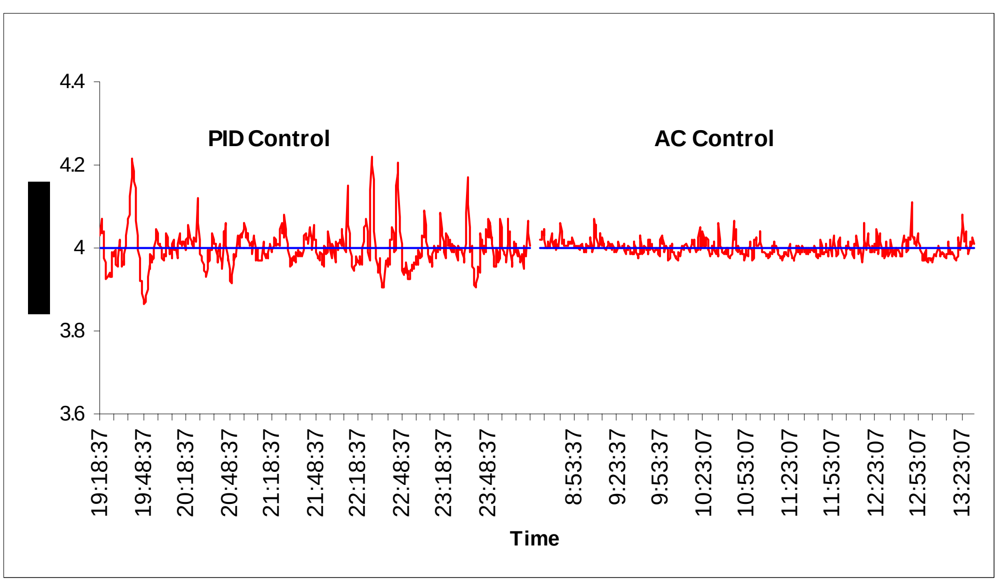

Figure 4. Saveall Consistency Control Comparison

adjust the set point for the compensated brightness controller located at the bleach tube. The operator tends to over bleach to ensure that the reel brightness is above the required minimum and this results in higher production costs for the paper. The advanced controller (AC) was configured to provide direct, automatic control of reel brightness by adjusting the set point of the upstream bleach flow controls. A control performance comparison over a period of about four days is shown in Fig. 6. Results indicate a reduction in reel brightness variability of about 83% compared to the existing control scheme used at the mill. The estimated annual savings in reduced bleach and reduced off specification paper is about $150,000 USD.

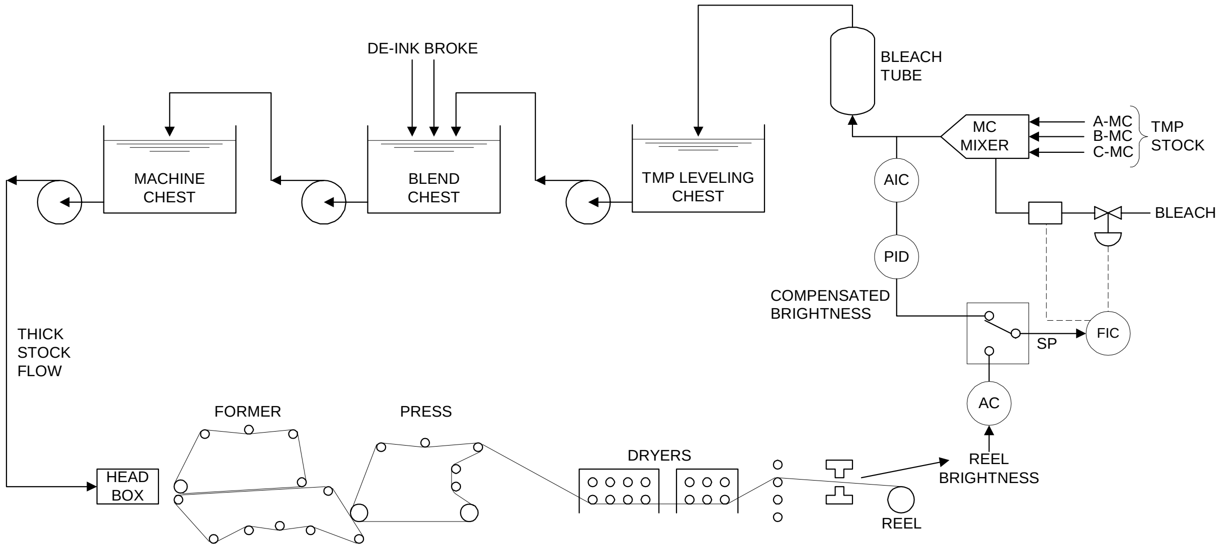

Figure 5. Simplified Reel Brightness Control Schematic

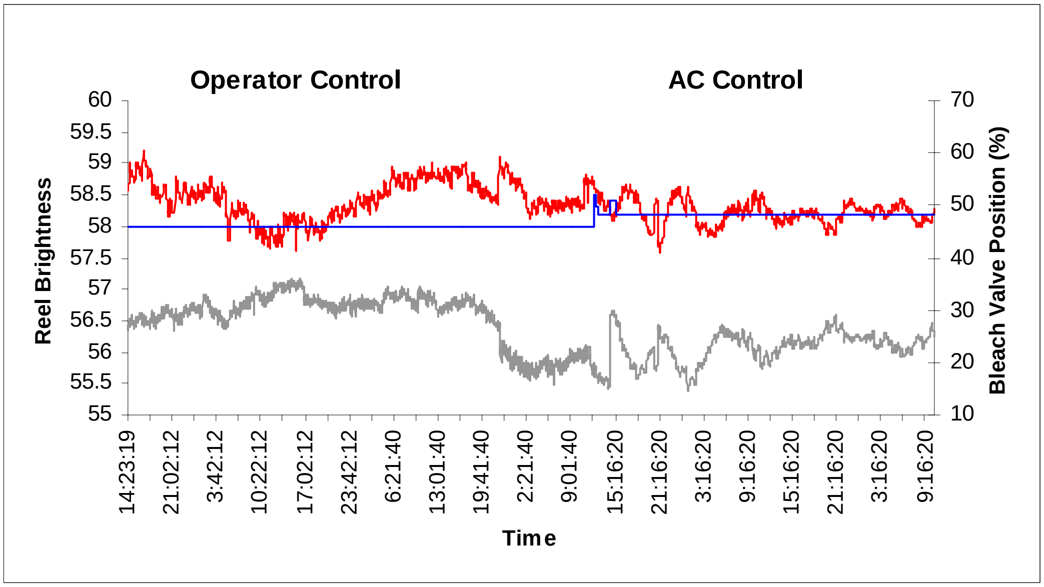

Figure 6. Reel Brightness Control Performance Comparison

CONCLUSIONS

The application of the advanced controller to the steam header pressure, saveall consistency and reel brightness control problems demonstrates the ability for paper makers to significantly improve their process control with a relatively simple regulatory control tool. The economics of the projects were very attractive with payback times of about a month. The problems of long development time, long setup time, repeated tuning and poor reliability associated with other advanced controllers such as Smith Predictor and other model-based controller designs are solved with this method.

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REFERENCES

[1] **Zervos, C.C. and Dumont, G.A** (1988): "Deterministic Adaptive Control Based on Laguerre Series Representation", Int. J. Control, 48, 2333-2359.

[2] **Dumont, G.A. and Zervos, C.C.** (1986): "Adaptive Control Based on Orthonormal Series Representation", 2nd IFAC Workshop on Adaptive Systems in Signal Processing and Control, Lund, Sweden, 371-376.

[3] **Zervos, C.C., Bélanger, P.R. and Dumont, G.A.** (1988): "Controller Tuning Using Orthonormal Series Identification", Automatica, 24, 165-175.

[4] **Elshafei, A.L., Dumont, G.A. and Elnaggar, A.** (1994): "Adaptive GPC Based on Laguerre Filters Modeling", *Automatica*, v. 30, no. 12, pp. 1913-1920.

[5] **Dumont, G.A. and Fu, Y.** (1993): "Nonlinear Adaptive Control via Laguerre Expansion of Volterra Kernals", Int. J. Adaptive Control and Signal Processing, V. 7, no. 5, pp. 367-382.

[6] **Fu, Y. and Dumont, G.A.** (1993): "Optimum Laguerre Time Scale and its On-line Estimation", IEEE Transactions on Automation Control, V. 38, no. 6, pp. 934-938.