6 Adaptive modell-prädiktive Regelung der Prozesse in Zellstoff- und Papierfabriken

Model-based predictive adaptive control of pulp and paper mill processes

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Abstract

This paper describes the application of a model based predictive adaptive process controller on a number of challenging pulp and paper mill control loops including paper machine reel brightness control, lime kiln temperature profile control, slaker temperature control, and Extraction Stage pH control. These loops are difficult to control due to the time delay present in the response. Consequently, many of these processes are manually controlled resulting in inefficient operation and increased operator work load. Paper making includes many such processes that cannot be well controlled with conventional PID techniques. Model predictive control provides a practical alternative to achieve significant reduction in process variability to reduce operating costs.

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1 Introduction

Paper making presents many challenging control problems due to the long response times present in several key areas of the paper making process. Processes with long response time and long time delays are difficult to control with conventional PID technology and are often manually controlled by the operator resulting in high process variability and increased operating costs. Examples of such processes include the control of digester level, temperature, and kappa number, pulp brightness and pH control in the bleach plant, lime kiln temperature and recaust controls, TMP refiner load control, and many paper machine processes. Due to the high variability inherent in the mill feed stock, the controls must deal with frequent disturbances in order to maintain the process at the specified targets. The difficult control dynamics of these key paper making processes, combined with the need for optimal disturbance rejection to achieve low production cost, presents an opportunity for the application of advanced control techniques.

Advanced control is a broad term that includes everything from complex PID based control strategies to supervisory optimization systems. However, to address the fundamental control requirements of the key paper making processes, what is needed is a regulatory level controller that can handle the long response times and process disturbances better than conventional PID control. Model predictive control (MPC) is a well proven method for dealing with long process time delays. It also provides an elegant framework for including measured disturbances as feed forwards in the control design, and can also solve multivariable systems such as interacting control loops using the same design methodology. In short, model predictive control provides a good solution for most of the common control problems where PID control does not perform well, making it the ideal alternative for papermakers to optimize the control of their plants.

MPC allows paper makers to approach their control problems using a consistent method that is based on understanding the process response. MPC forces the control technician to examine the process response and eliminates the ability to just dial down the PID tuning parameters until stable control is achieved. This step ensures that the actual changes that are occurring in the process response itself are recognized so that the control solution can be modified to address and solve the problem. By doing so, MPC helps the control system evolve to a more complete and optimal solution, compared to the typical PID approach which leads to the controller being de-tuned to a lowest common denominator solution that is stable under all plant conditions but is optimal for none.

Historically, model predictive control has been difficult and expensive to implement due to the implementation effort and the level of expertise required to apply the technology. This is due to several factors, including the complexity of the model to be developed as well as the academic nature of many of the software tools developed to implement model predictive control techniques.

This paper describes the application of a model-based predictive adaptive (MPC) controller, commercially known as BrainWave®, to various paper making processes. This controller is a patented (US Patent #5,335,164) PC-based commercial software package with over 1,000 installations around the world in many different process industries. The predictive control capability enables significant performance improvements compared to manual or other automatic control strategies. Variability reductions of 50% or more are typically achieved using this technique.

As discussed, obtaining a process response model is a key part of the implementation of an MPC controller. In our design, the controller models the system response using a generic function series approximation technique based on Laguerre polynomials. This approach provides a simple and efficient method to mathematically model the process response with a minimum of a priori information. It also enables the controller to perform online adaptation of the process response models automatically. These factors reduce the implementation effort and contribute to quick installation times for the MPC controller, typically about 1 week per application. The adaptive capabilities assist the control technician with developing the process response models, so the same good result will be achieved regard-

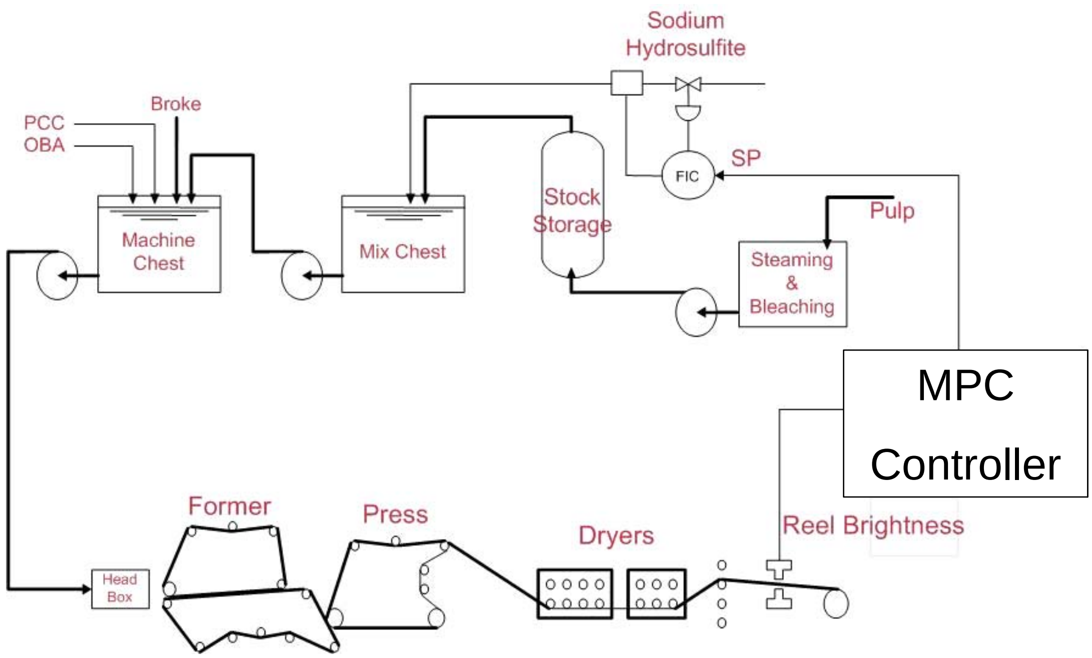

Figure 1: Reel Brightness Control Scheme

Figure 2 shows a four day period of MPC control of reel brightness. It can be seen that a number of set point changes are made by the operator, ranging from 75 ISO down to 60 ISO. Initially the lower limit for the sodium hydrosulfite flow was set to 2 gallons/minute; this was lowered to 1 gallon/minute, then finally 0.5 gallon/minute since the sodium hydrosulfite flow is being continually manipulated by the controller.

Results from the first 2 months of production are shown in Table I. These results indicate a significant reduction of sodium hydrosulfite consumption per ton of paper production. Operation during February was a mix of manual control and MPC control as the MPC was commissioned during this period so chemical savings during this period are only due to the fraction of the time that the MPC was in control of the process. The higher brightness grades show a reduction in chemical consumption of between 15 and 75% comparing January production (prior to the MPC installation) with March production (when fully controlled by the MPC). For example, comparing the production of the very high brightness 83 grades, a reduction of 44% was observed. For this mill, the annual chemical consumption was typically in excess of $500,000 USD. A reduction of 40% provides annual savings of about $200,000 USD, resulting in a project payback period of less than 6 months.

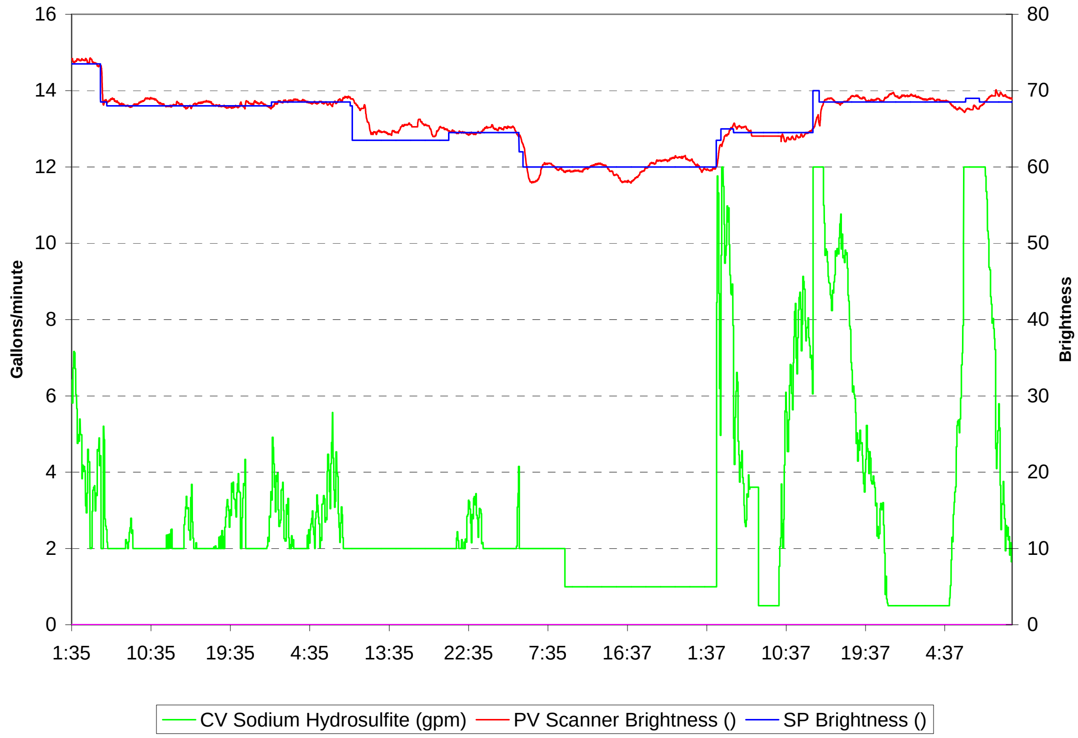

Figure 2: Scanner Brightness Performance in MPC Control

Table I: Sodium Hydrosulfite Consumption

	Sodium hydrosulfite lb/Paper Tons			**% Reduction Jan-Mar**	**% Reduction Feb-Mar**
Target Brightness	January (Manual Control)	February (Commissioning)	March (MPC Control)		
75	9.49	7.53	2.28	75.96	69.7
80	8.79	11.35	7.41	15.71	34.7
83	-	18.93	10.59	-	44.1

4 Lime Kiln Control

Lime kiln temperature profile is typically manually controlled due to the long time delays and multivariable interactions of the draft and fuel on the kiln temperature profile that make automatic control with PID impractical. Response times of one hour or more are typical. Operators are often impatient with the long response time of this system and tend to make large corrections to the fuel feed rate in an attempt to recover the temperature profile quickly during process disturbances such as production rate changes. These actions result in extremes of temperature in the kiln, leading to ring formation problems as well as reduced refractory life. Operators also tend to control the temperature profile at a higher value than necessary for the lime burning and at a high excess oxygen level to provide a comfortable operating margin that requires less frequent attention. These practices lead to increased fuel consumption and maintenance costs.

Adjusting draft and fuel cause shifts in the flame length and excess oxygen levels. In addition to the long response times, this interaction must also be addressed by the control strategy to achieve responsive yet stable control performance. The ultimate objective of the control strategy is to maintain a constant lime discharge temperature to ensure consistent lime quality as measured by LOI and reactivity (slaking rate). A supervisory MPC controller is used to control the lime discharge temperature by adjusting the target for the feed end temperature controller. This approach allows feed end temperature limits to be easily included in the control strategy. A schematic of the control scheme is given in Figure 3.

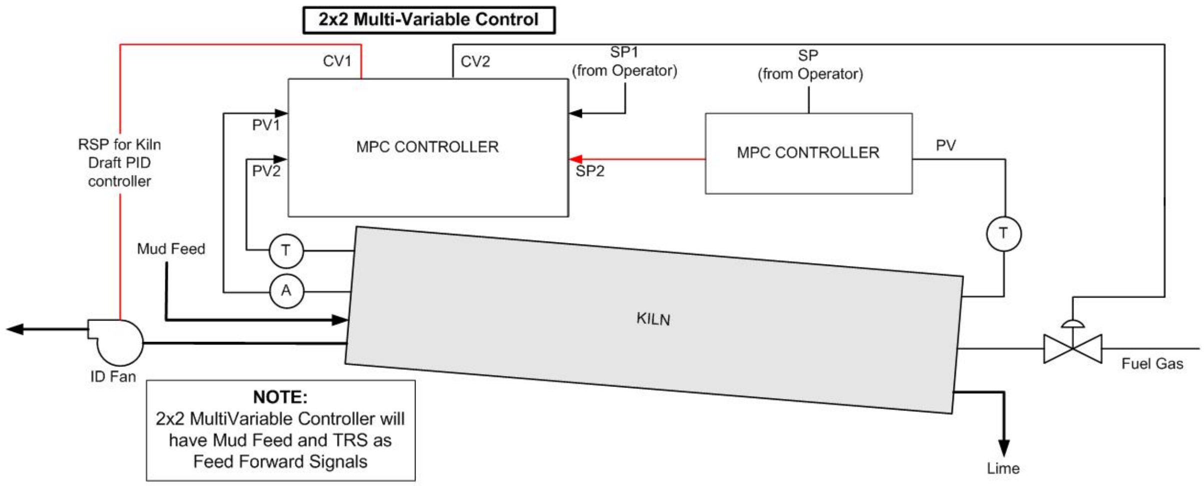

Figure 3: Lime Kiln MPC Control Scheme

Figure 4: Lime Kiln Control Comparison