# Mathematical Modeling and Model Based Control of a Pulp Mill Powerhouse

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The powerhouse of a Kraft pulp mill process typically consists of a recovery boiler, a power boiler and turbogenerators. The recovery boilers are unique to the Kraft process, because they are used both to burn the extracted wood components to produce superheated steam and also to regenerate the alkaline cooking chemicals. Power boilers utilize the off-size chips and bark, and they are used to aid the recovery boilers in the production of superheated steam. The superheated steam is then used in the turbogenerators to provide electricity to the mill and to produce various grades of process steam. The process steam and the regeneration of cooking chemicals are essential for the pulping processes and this fact increases the importance of reliable control of the powerhouse for safe and smooth mill operation.

Control of boiler systems gathered research attention since the invention of the steam engine and they kept being the focus of many mathematical modeling and control studies with a wide range of applications from nuclear power plants to ship boilers. The recent first principles drum-boiler model of Astrom and Bell is noticeable for its coverage of all the important aspects of boiler operation [1, 2]. Many advanced control studies of boiler systems with H-infinity, gain scheduling, L1 optimal control and other multivariable control methods can also be found in the literature [3, 4, 5]. In a more relevant work to the process industries, Luyben studied the modeling and control of a multiboiler steam generation system [6].

In this work, the powerhouse of an actual industrial pulp mill with a recovery, and a power boiler was analyzed for process control applications. The main goal was to understand the interactions and dynamics of the water levels in the two boilers and the pressure in the common superheated steam header. For this purpose, first principles dynamic models of the boilers were developed according to the work of Astrom and Bell [1]. Fire side dynamics were modeled as first order plus time delay systems to include the effects of burning different fuels. At this stage, simulations were used to investigate the different behavior of the two boilers in the face of various process disturbances.

As a next step, the actual control structure in the mill was added to the powerhouse model. In this formulation, the firing rate of the power boiler was adjusted by a plant master controller according to the pressure variations in the common steam header. Conventional three-element level controllers were used to preserve the drum levels in the two boilers. Simulations were conducted to compare the performance of this base case with alternative decentralized control strategies to evaluate the effects of different control elements. Finally, a model predictive controller (MPC) was developed to maintain the water levels of the two boilers and also to control the common header pressure. The Jacobian of the nonlinear powerhouse model at the nominal operating conditions was used to obtain a 12 state linear model of the system and this linear model was used to design a state space based MPC controller with 3 inputs (the firing rate of the power boiler and the feedwater flowrates to the boilers) and 3 outputs (the common header pressure and the two drum levels). The performance of the MPC design in handling sudden changes of steam demand was compared with the decentralized formulations. The results showed that the MPC was significantly more effective in controlling the steam header pressure. On the other hand, even though the MPC was able to settle the drum levels in shorter time, the drum level swings from the setpoints were still comparable with the decentralized control formulations.

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