

Developing Simulation Models for Dynamic Optimization

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Abstract

Dynamic optimization based on simulation is extremely time consuming. The quest for the optimal solution requires a vast number of iterations. Since the simulation is performed at each iteration step, the decrement of the simulation time becomes crucial. This paper presents the development of simulation models for dynamic optimization. The area of interest is paper and pulp industry. The keyword for the modeling is simplicity. Simplicity speeds up the simulation and decreases the time needed for the optimization.

1 Introduction

The efficiency of the production is always questioned as the market prices go down. The optimization of processes cuts down costs and creates savings. The optimization procedures benefit from the fast modern computers but the calculation takes still a lot of time. Some processes can be defined analytically as a function or a set of functions. As more complexity is added to the model, a simulator is needed and precious seconds lost. The simulation time is strongly dependant on the simulation software used. MATLAB SIMULINK offers a versatile platform for the simulations and the optimization can be done within MATLAB. Together they form a good tool for the research.

This paper presents a selection of models created for the simulation of pulp and paper industry's processes. The models have been created to fulfill the needs of the optimization. The models are also designed to produce results that are easily understood by the line operators. This means that the output of the models matches the signals measured from the process. The starting point for the research was academic enthusiasm, but along with the progress, the funding companies benefit from the results as their processes are optimized.

2 Simulation Model Library for Pulp and Paper Industry

This chapter presents the first three components of the SIMULINK model library built. Controllers, tanks and valves are basic components of the processes. Controlling flows and tank levels offers many interesting optimization problems.

2.1 PID -controller

PID –controller is the most widely used controller. Although its basic structure is very simple, it can be used for various control tasks. The popularity makes the basic tuning principles of the PID –controller very well known [2, 9]. The input of the controller is the residual of the target value and the measured signal. The output is calculated as a sum of terms P-, I- and D. P stands for a proportional term, I for integrative and D for derivative. The most popular combination is PI.

The controller used in the processes discussed is Damatic XD. The function of the Damatic XD can be expressed with the equation

$$con = K_p \left(e + \frac{1}{T_i} \int edt - D \right) + k_{ff} m_{ff} + bias \quad (1)$$

$$D = T_d \frac{d}{dt}(me) - T_{df} \frac{d}{dt}(D),$$

where

- e = residual
- con = output
- me = measured value
- K_p = gain
- T_i = integration time
- T_d = derivation time

In the simulated processes PI –control is used. Therefore the equation (1) simplifies into

$$con = K_p \left(e + \frac{1}{T_i} \int edt \right) \quad (2)$$

The simulation model of the controller can be build from the basic blocks of the SIMULINK. The schematic of the simulation model is presented in the figure 1.

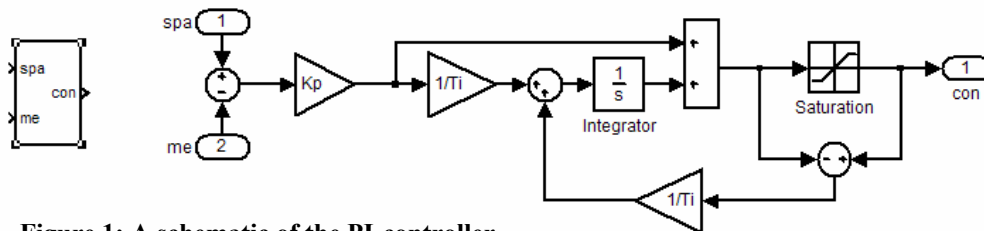


Figure 1: A schematic of the PI-controller

The simulation model realizes the equation (2). The inputs are measured signal (me) and target value (spa). The tuning parameters are gain K_p and integration time T_i . The feedback loop defines an AntiWindUp –operation. This operation ensures that the controller stays on the operation range. If the WindUp effect is not taken into account, the controller may continue integration although the limit is already reached. *Saturation* –block limits the output and the feedback loop reduces the over integrated part. The user controls the simulation model by giving values for the parameters K_p and T_i .

2.2 Control Valve

Each control valve functions differently, even if the type and the manufacturer are the same. Aging and different compositions of a flow affect every valve in a different way. Therefore a certain simulation model can not describe the variety of valves. However, if the model is flexible it can be personalized to match the actual target. The function of the control valve can be described in detail with complex differential equations [6, 7]. This approach requires several specific parameters to be adjusted. In order to adjust all the parameters, detailed information about the valve is needed. In most cases this information isn't easily available.

The SIMULINK model is based on identifying the non-linearity and hysteresis of the control valve. The model is constructed from three basic blocks of the SIMULINK. The hysteresis block gives a value for the hysteresis. The non-linear operation is described with the function block and the saturation block gives lower and upper limits for the operation area. The Figure 2 shows the schematic of the SIMULINK model.

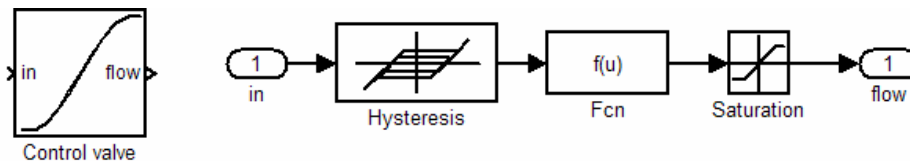


Figure 2: A schematic of the control valve

The description of the non-linearity is accomplished by curve fitting. As the input the function block gets four points from the operation area. Two of them define the lower and upper limits and the other two can be adjusted to ensure the best possible compatibility with the actual valve. Using these four points the function block is initialized by fitting a third degree polynomial to work as an operation line. The adjustment can be done manually or with the tuning tool.

The tuning tool sets the parameters so that the output of the model matches the signals measured from the process. The tuning is actually a simple optimization problem, which can be formulated for example as a least squares problem and solved with MATLAB –function *lsqnonlin*. This function uses the Levenberg-Marquardt –algorithm [1].

2.3 Tank

The simulation model for the tank is based on known flows and consistencies. Figure 3 presents a schematic of the model. The inputs are incoming flow and a demand for the outflow i.e. rate of the pump. The third input initializes the model. The flow is described as a vector which cells define the fractions of the consistency components. The flow can for example be divided into three components: water, mechanical pulp and chemical pulp.

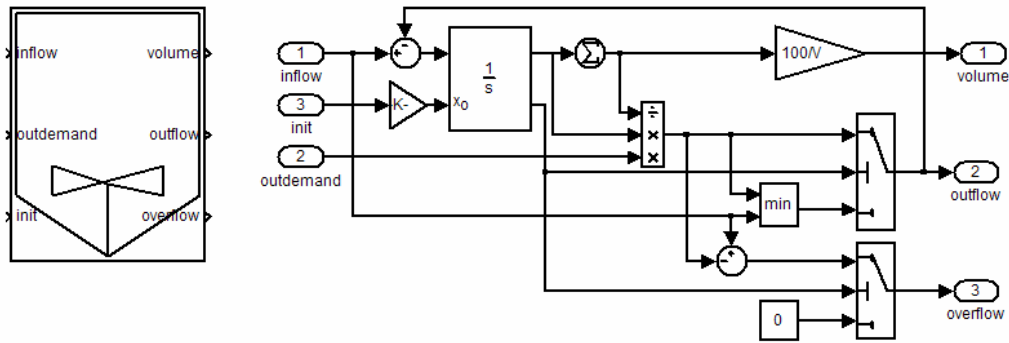


Figure 3: A schematic of the tank

The simulation model is based on the assumption, that the mixing in the tank is complete. It calculates the volume of the tank, the outflow and the possible overflow.

3 Creating Process Models

Created simulation models can easily be connected to each other to form complete process models. Usually some extra blocks are needed to simulate the process behavior. The need for additional blocks depends on the planned use of the simulator. The simulation model can be used in various ways:

- to gather the necessary information
- to solve a problem
- as a training tool
- both as a training tool and for solving a problem
- as an on-going scheduling tool

When the model is driven by the optimizer, to solve a problem, the speed of the simulation is essential. All extra features like displays and unwanted outputs are removed. The parameterization of the model must be done so that the optimizer can run the model. The problem formulation sets requirements for the simulation model. The inputs and outputs must be chosen and controlled correctly to get the information the optimizer requires.

The time series that the simulation model creates are used in calculating the objective function. One task is to find the optimal solution, another task is to make sure that the solution is reliable. It is relatively easy to create models by adding components but validating and calibrating the model is often difficult. Validation ensures that the model corresponds to reality. Calibration checks that the data generated by the simulation matches real (observed) data.

An example of the process model is shown in the figure 4. Using presented components a part of the paper machine, apportioning of the pulp, is simulated. The model consists of several tanks, control valves and PI-controllers.

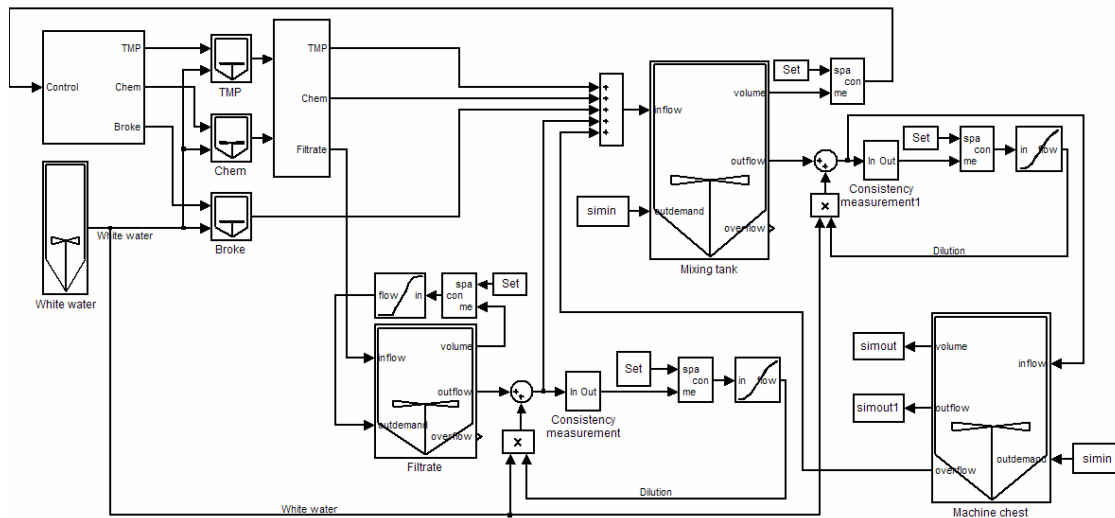


Figure 4: A schematic of the apportioning section of the paper machine.

The model has been used to tune the parameters of the separate controllers, to optimize the behavior of the process by controlling tank volumes and flow rates. It has also functioned as a monitoring tool. It has shown control valve malfunctions and given information about the accuracy of the consistency measurements.

4 Conclusions

The simulation models presented in this paper have been successfully used. They have been used as separate tools to monitor and develop the processes. They have also been run by the optimizers. Creating models with SIMULINK requires some extra effort compared to the use of tailored modeling software. The time spent on developing models is partially compensated with the gained overall picture of the problem field. Developing models from the scratch creates a deeper understanding of the process which is important when defining the optimization problem. Knowing both the simulation and the optimization environment is beneficial, at least at the researcher point of view. The development of the models and the optimizers is carried on in the future projects. Next target is to create an online optimization tool for the paper mill personnel.

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