Characterization Feedback and Feedforward Compensators to Regulate the Temperature of Heat Exchanger

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Abstract: Heat exchangers are used in order to transfer heat from one hot fluid through the solid wall to a cold fluid. There are various types of heat exchangers in industry. These heat exchangers apply in fields such as condensation, electricity production, chemical processes, medicine, etc. In the presented work a feedback and feedforward compensators to regulate the temperature of heat exchanger is characterized.

***Index Terms*: Heat exchangers, Feedback and Feedforward Compensators.**

I. INTRODUCTION

The investigation of feedforward-feedback control of an inverter-based compensator evolves from a previous investigation developed by [1]. In this research, an approximate linearized model was developed in order to characterize the fundamental frequency behavior of the compensator. This average model uses one parameter of control denominated as 6, and represents a phase shift between the network voltage and the fundamental component of the inverter voltage. The control algorithm installed on the actual laboratory prototype was implemented using a TMS320C30 digital signal processor. The experimental results of [2] showed that the approximate average model represented very well the fundamental frequency behavior of the laboratory prototype under stationary and dynamic conditions. Nevertheless, one of the problems found by [2] in the laboratory prototype was the inability of the compensator to maintain a unique constant value for the link voltage in all the operability range of 6.

The present investigation explores strategies to overcome some of the problems encountered in the compensator built by [1]. It also extends the theoretical knowledge about the behavior in stationary and dynamic conditions of the actual laboratory prototype and explains in greater detail the results achieved by [2]. The drawbacks encountered in the previous research are overcome by including one more variable of control. Since the system is modeled not only by considering the fundamental frequency components, but also by using other mathematical techniques that make no approximation, the results achieved with the latter model validate the results obtained with the former. Furthermore, when the parameter and control strategies of the resultant exact mathematical model are set equal to the actual laboratory prototype, the theoretical
Results achieved with the former model agree with the results of the compensator developed and presented in literature.

II. REFERENCE VALUES AND SIGNAL SAMPLES

One of the problems encountered in the preceding research was how to calculate the reference voltage value for the laboratory prototype. This problem was solved by a piecewise linearization of a nonlinear experimental curve [3]. The present investigation presents precise equations to calculate the reference voltage and current values for the exact model. This model is used to represent the actual laboratory prototype. It also analyzes the consequences of sampling at the wrong time and suggest the appropriate criteria to overcome this particular problem.

III. FEEDBACK CONTROL

A block diagram representation of the open-loop process is shown in figure 1.[4]

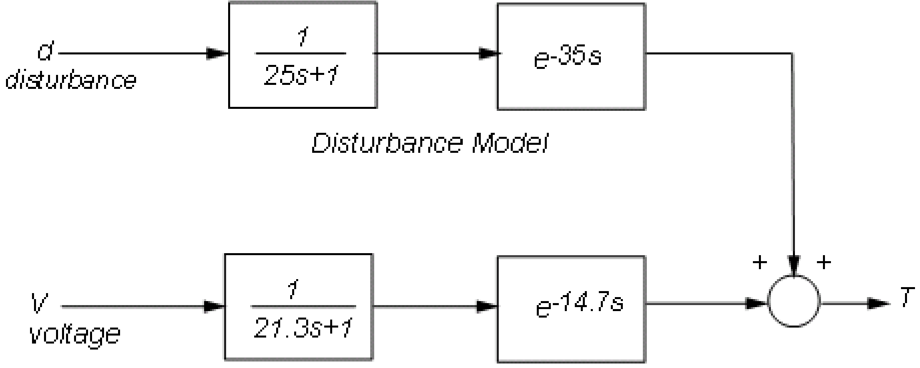

Figure 1: Block Diagram for Open-Loop Process.

The transfer function

$$G_p(s) = \frac{e^{-14.7s}}{21.3s+1} \tag{1}$$

This models how a change in the voltage V driving the steam valve opening affects the tank temperature T, while the transfer function

$$G_d(s) = \frac{e^{-35s}}{25s+1} \tag{2}$$

and how a changed in inflow temperature affects T. To regulate the tank temperature T around a given set point Tsp, we can use the following feedback architecture to control the valve opening (voltage V). In this configuration, the proportional-integral (PI) controller

$$C(s) = K_c\left(1 + \frac{1}{\tau_c s}\right) \tag{3}$$

Calculates the voltage V based on the gap Tsp-T between the desired and measured temperatures.

IV. FEEDFORWARD CONTROL

As the changes in inflow temperature are the main source of temperature fluctuations of the system. Therefore to reject such disturbances, an alternative to feedback control is the feedforward architecture shown in figure 2 [5].

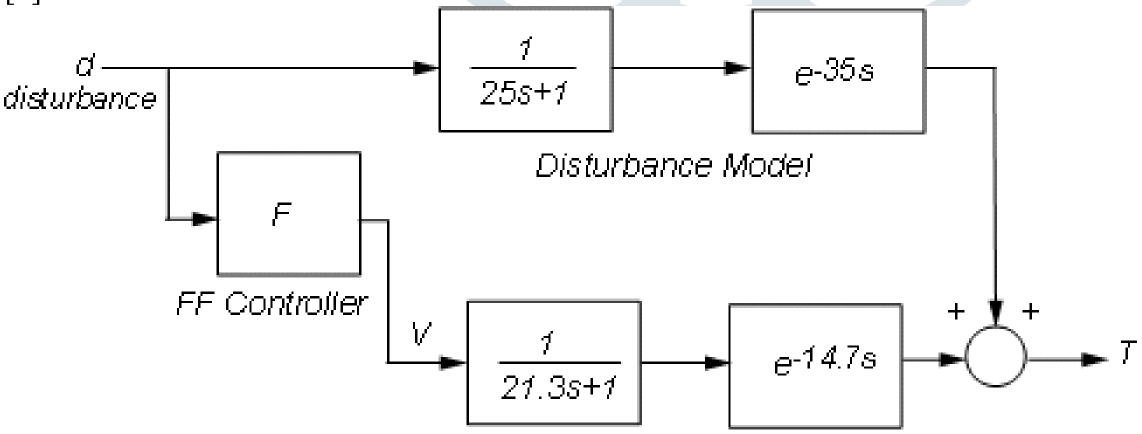

Figure 2. Block diagram for Feedforward Control.

In this configuration, the feedforward controller F uses measurements of the inflow temperature to adjust the steam valve opening (voltage V). Feedforward control thus anticipates and preempts the effect of inflow temperature changes [6-7]. Straightforward calculation shows that the overall transfer from temperature disturbance d to tank temperature T is

$$T = (G_p F + G_d)d \tag{4}$$

Perfect disturbance rejection requires

$$G_pF + G_d = 0 \rightarrow F = -\frac{G_d}{G_p} = -\frac{21.3s+1}{25s+1}e^{-20.3s} \tag{5}$$

V. RESULTS AND DISCUSSIONS

In the presented work modeling inaccuracies prevent exact disturbance rejection, but feedforward control will help minimize temperature fluctuations due to inflow disturbances. The used simulation setup is a first-order-plus-dead time model of the heat exchanger characterized. By initializing a step disturbance in valve voltage V and record the effect on the tank temperature T over time. The measured response in normalized units is presented. Different graphs for variation in temperature of the system, disturbance in system due to temperature variation and uncertainty of the system stability due to temperature variation are presented. Different values of the obtained parameters i.e. Maximum and minimum value, peak to peak value, mean value, RMS value, Rise time, Slew rate are presented in the table 1.

Table 1. Comparison of different values obtained for different parameters

S. No	**Signal Statistics**	**Temperature**	**Disturbance**	**Uncertainty**
1.	Maximum Value	1.497e-01	0	1.031e+00
2.	Minimum Value	-2.385e-02	-1.000e+00	0.000e+00
3.	Peak to peak value	1.736e-01	1.000e+00	1.031e+00
4.	Mean value	1.191e-02	-9.206e-01	8.159e-01
5.	RMS value	3.890e-02	9.206e-01	8.952e-01
6.	Rise Time	4.050 seconds	-----	1.734 seconds
7.	Slew Rate	29.485	-500.00	456.654

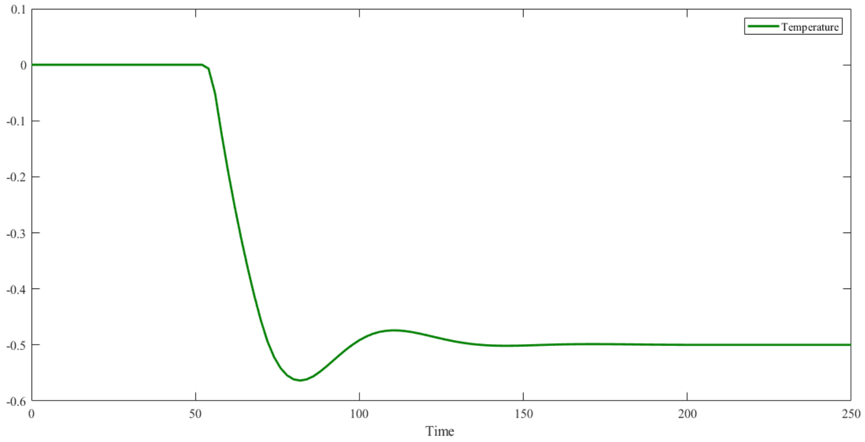

Figure 3. Presents the Temperature variation of the system

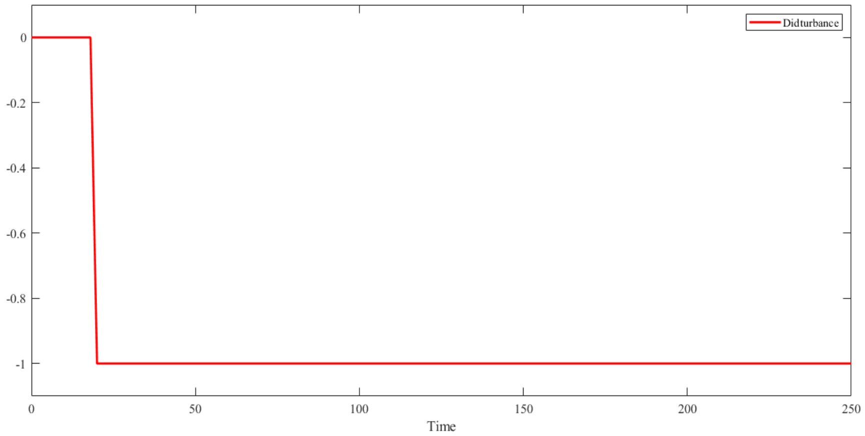

Figure 4. Disturbance in system due to temperature variation

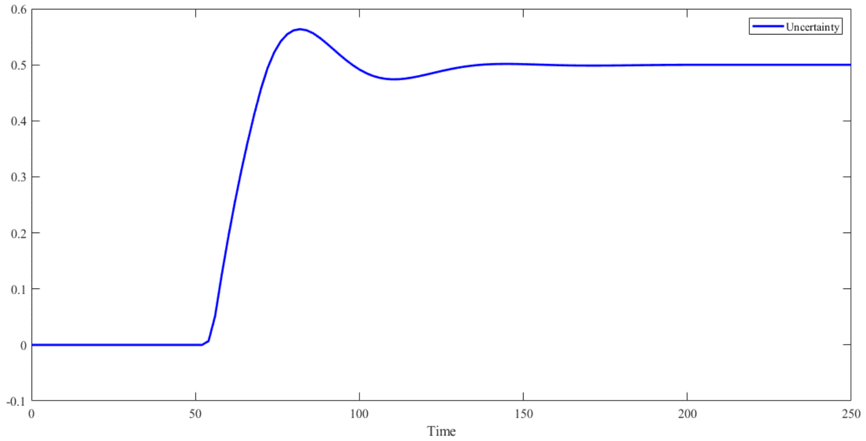

Figure 5. Uncertainty of the system stability due to temperature variation

VI CONCLUSION

A feedback and feedforward compensators to regulate the temperature of heat exchanger is characterized. A loop has been closed and the response to a set point change has been simulated. From simulation results, it has been concluded that the response is fairly fast with some overshoot. The stability margins confirm that the gain margin is weak. Further experimentation could be carried out to estimate the first-order response to a step disturbance in inflow temperature.

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