CHAPTER 6

CONCLUSION

6.1 GENERAL

This chapter aims at reviewing the contributions made during the course of this work and proposing a few suggestions for future work. Before proceeding with the review of the work done, the objectives of this thesis stated earlier are recalled.

The main objective of this thesis has been to investigate the identification and control of nonlinear systems. This thesis specifically aims at the proposal of identification and control method for Wiener-type nonlinear system and gives the best implementation of real-time operation. Further, the thesis also aims at validating the identification and control method to simulated stable, unstable, real-time heat exchanger and three-tank systems.

6.2 REVIEW OF THE WORK DONE

This Section summarises the major achievements of the work in chapter wise. They are summarised below:

(i) Chapter 2 addresses the control problem for CSTR exhibiting input multiplicity and non-minimum phase behavior. A Wiener model based NPID controller is designed for an isothermal CSTR and compares the performance with PID controller. The Linear dynamic subsystem is in the form of second order transfer function and their parameters are
obtained by linearizing the nonlinear differential equation around an operating point. Continuous piecewise polynomial is fitted to calculate the static nonlinear gain subsystem. NPID control strategy is able to track set point changes and reject load disturbances. Performance index like ISE, IAE and the time domain specifications are compared with PID and gives better results. Control of CSTR by the NPID based on Wiener model has much superior performance to that of the PID controller in all range.

(ii) Approximation of static nonlinearity can vary from algebraic equations to NN. NN is popularly used for the identification and control of nonlinear dynamical systems without prior knowledge. Model predictive and inverse neural controllers are designed for CSTR process. In this study the performance of the neural controllers are evaluated in simulation for both servo and regulatory problems and the results are compared with PID. Among the four controllers such as PID, Wiener model based NPID and NPC and NIC designed for CSTR, NIC controller shows a good dynamic performance for both servo and regulatory operation when compared with others.

(iii) The control of heat exchanger is complex due to its nonlinear dynamics, particularly the variable steady-state gain and the time constant of the process fluid. A real-time heat exchanger is modeled as Wiener by the method of Huang et al (1998) and controlled by Lee et al (2004) using RFT. Symmetric and asymmetric RFT are conducted for the heat exchanger process by the method of Huang et al (1998). First, the symmetric RFT output data is used to obtain the static nonlinearity. An
objective function that aims to change the asymmetry to symmetry, in the system output is formulated. A standard optimization procedure is used to minimize this objective function by adjusting the polynomial parameters that is used to represent the nonlinear gain of the Wiener model. In the Second step, asymmetric RFT output is used to obtain a linear subsystem as FOPDT.

An on-line procedure is used to obtain the static nonlinearity by Lee et al (2004) method. Different degrees of systems are illustrated to facilitate the understandings of these two RFT methods. Amplitude of the periodic output ($k_u$) and the ultimate period ($p_u$) are obtained by RFT. PI parameters are obtained directly from these two parameters. The Wiener model based controller is compared with that of the linear PI controller in real-time. It is proved that the real-time heat exchanger can be modeled and controlled by the RFT methods.

(iv) A new method for identifying a Wiener model using a RFT is proposed. This identification procedure is formulated based on the industrial process. The identification procedure is divided into two parts. In the first part, the linear subsystem is assumed as FOPDTs and their parameters are identified by conducting RFT for the nonlinear process. In the second part, the parameters of the nonlinear subsystem and its inverse are determined via a simple optimization procedure. This method avoids the iterative procedure. By this approach, the identification of the linear and nonlinear parts are fully decoupled. With the obtained Wiener model, the PI controller
is designed by RFT. Nine simulated case studies including unstable systems, a real-time heat exchanger and a three tank a process shows the effectiveness of this proposed method.

A limitation of this method is that it can be used for mildly nonlinear process. In the view of the practical applications, the proposed method has advantages over the existing methods. First, single RFT data is sufficient for identification of the linear and nonlinear subsystem. Second, linear system identification can be improved by careful determination of dead time. Third, both the linear and nonlinear parts are separately identified in offline. Finally, an ON-OFF controller is used to identify the Wiener model, but the existing methods use the modified relay that needs a computer based interface to vary the height of the relay.

Relay with hysteresis can be used to eliminate noise and biased relay can be used to eliminate disturbances. Finally, it identifies the process information around the important ultimate frequency (\(\omega_u\)). Wiener model identification and control can be effectively implemented in real-time using RFT than the conventional methods. This proposed method is designed in such a way as to suit real time process identification and control.

The proposed method is having many advantages. It is

- simple and effective for both identification and control in single test
able to work in the rough and rocky areas such as process and petrochemical industries in real-time.

- most suitable for real-time implementation and control.
- designed in such a way to adapt the 95% operated PID

6.3 SCOPE FOR FUTURE WORK

Identification and control of Wiener-type processes using RFT can be extended to with relay with dead-time, relay with hysteresis, relay with saturation, biased relay, two channel relay, etc. Local Wiener models from RFT can be scheduled using the fuzzy switching. Identification and control can be extended also for load disturbance and noise.

Wiener model and controller has been developed and tested for limited output range due to the limitation of operating range in the physical heat exchanger and three-tank systems. The same concept can be extended for wide operating range and can also be attempted on the analysis of feed forward control.