List of Figures

Fig. No.	Figure Caption	Page No.
Fig. 1.1:	General process system	4
Fig. 1.2:	Hierarchy of the various control approaches used in process industries [11]	7
Fig. 3.1:	CSTR with a first-order chemical reaction.	35
Fig. 3.2:	Open-loop response curve using MATLAB/SIMULINK	37
Fig. 3.3:	Bioreactor temperature control loop	39
Fig. 3.4:	Open-loop response for bioreactor temperature	44
Fig. 3.5:	Open-loop response for jacket temperature	45
Fig. 3.6:	Open-loop response for Ethanol concentration	45
Fig. 3.7:	Open-loop response for substrate concentration	46
Fig. 3.8:	Open-loop response for dissolved oxygen concentration	46
Fig. 3.9:	Open-loop response for biomass concentration	47
Fig. 3.10:	Measured and simulated model output of the nonlinear process model	47
Fig. 3.11:	Simple unity feedback control loop	52
Fig. 3.12:	(A) Evolution of IMC Controller (B) IMC control structure	57
Fig. 3.13:	(A) Internal Model Control (IMC) structure(B) Feedback control system	60
Fig. 4.1:	SIMULINK closed-loop control structure of various models.	72
Fig. 4.2:	Closed-loop response for set-point and load change using SIMC [46] tuning rule	73
Fig. 4.3:	Closed-loop response for set-point and load change Åström and Hägglund [20]	73
Fig. 4.4:	Closed-loop response for set-point and disturbance change using optimization tuning rule	74
Fig. 4.5:	Closed-loop responses of a unit step change in setpoint and load for EX 1	78

Fig. 4.6:	Closed-loop responses of a unit step change in setpoint and load for EX 2.	79
Fig. 4.7:	Closed-loop responses of a unit step change in setpoint and load for EX 3.	80
Fig. 4.8:	Closed-loop responses of a unit step change in setpoint and load for EX 4.	81
Fig. 4.9:	Closed-loop responses of a unit step change in setpoint and load for EX 5.	82
Fig. 4.10:	Closed-loop responses of a unit step change in setpoint and load for EX 6.	83
Fig. 4.11:	The plot of Ms against λ (Ex. 1)	84
Fig. 4.12:	The closed-loop responses for (A) setpoint and load change of different tuning rules and (B) their corresponding control action (Ex 1).	86
Fig. 4.13:	The plot of Ms against λ (Ex. 2)	87
Fig. 4.14:	The closed-loop responses for (A) setpoint and load change of different tuning rules and (B) their corresponding control action (Ex. 2).	88
Fig. 4.15:	The plot of Ms against λ (Ex. 3)	90
Fig. 4.16:	The closed-loop responses for (A) setpoint and load change of different tuning rules and (B) their corresponding control action (Ex 3).	91
Fig. 4.17:	The plot Ms against λ (Ex. 4)	92
Fig. 4.18:	The closed-loop responses for (A) setpoint and load change of different tuning rules and (B) their corresponding control action (Ex 4).	93
Fig. 4.19:	The plot of Ms against λ (Ex. 5)	94
Fig. 4.20:	The closed-loop responses for (A) setpoint and load change of different tuning rules and (B) their corresponding control action (Ex. 5).	96
Fig. 4.21:	The plot of Ms against λ (Ex. 6)	97
Fig. 4.22:	The closed-loop responses for (A) setpoint and load change of different tuning rules and (B) their corresponding control action (Ex. 6)	98

Fig. 4.23:	Feedback control loop for temperature control of bioreactor	100
Fig. 4.24:	SIMULINK block diagram for feedback control loop for temperature control of bioreactor using PID controller	101
Fig. 4.25:	Closed-loop response of bioreactor temperature for set-point and load change.	102
Fig. 4.26:	Closed loop response of jacket temperature for set-point and load change.	102
Fig. 4.27:	Closed-loop response of inlet flow rate to the jacket for setpoint and load change	103
Fig. 4.28:	Closed loop response of c oncentration of ethanol corresponding to controlled reactor temperature.	104
Fig. 4.29:	Closed loop response of c oncentration of substrate corresponding to controlled reactor temperature.	105
Fig. 4.30:	Closed loop response of concentration of dissolved oxygen corresponding to controlled reactor temperature.	105