LIST OF FIGURES

Figure No.	Figure captions	Page No.
2.1	Stability in the sense of Lyapunov	24
2.2	Asymptotic stability in the sense of Lyapunov	25
2.3	Monotonic stability in the sense of Lyapunov	26
2.4	Four Stages of Optimization Process	31
2.5	Architecture of Fuzzy Logic Control	35
3.1	Closed-loop structure of magnetic levitation system	38
3.2	Open-loop response of magnetic levitation system	41
3.3	Step response of magnetic levitation system with PID	43
	controller tuned with T&E method	
3.4	Bode plot of magnetic levitation system with PID	44
	controller tuned using T&E method	
3.5	Distribution of marks obtained by learners taught by two	46
	different teachers	
3.6	Model for the distribution of marks obtained for a group	47
	of learners	
3.7	Block diagram for optimum search using TLBO	49
3.8	Step response of magnetic levitation system with	53
	parameters of PID controller tuned using TLBO	
	algorithm	
3.9	Bode diagram of magnetic levitation system with	54
	parameters of PID controller tuned using TLBO	

vi

algorithm

4.1	Step response of nonminimum phase system with and	60
	without Pade's first order approximation	
4.2	Step response of Nonminimum Phase System with PID	63
	Controller	
4.3	Bode Response of Nonminimum Phase System with PID	64
	Controller	
4.4	Step Response of Nonminimum Phase System with	68
	Smith Predictor	
4.5	Bode response of nonminimum phase system with Smith	69
	Predictor	
4.6	Hierarchy of GWO	70
4.7	Flowchart for obtaining parameters of PID controller	75
	using GWO	
4.8	Step Response of Nonminimum Phase System with	76
	GWO algorithm	
4.9	Bode Response of Nonminimum Phase System with	77
	GWO algorithm	
5.1	Free-body diagram of Inverted pendulum	83
5.2	Open-loop response of cart's position	89
5.3	Open-loop response of pendulum's angle	89
5.4	Block diagram of closed-loop control system	91
5.5	Closed-loop response of cart's position with PID	93
	controller	
5.6	Closed-loop response of pendulum's angle with PID	93

controller

5.7	Closed-loop response of cart's position with LQR	97
	controller	
5.8	Closed-loop response of pendulum's angle with LQR	97
	controller	
5.9	Conceptual Mechanism of Fuzzy logic control	100
5.10	Movement of Inverted-pendulum system mounted on a	101
	cart	
5.11	Membership function of error and change in error for	101
	cart's position	
5.12	Output membership function for cart's position	102
5.13	Membership function of error and change in error for	103
	pendulum's angle	
5.14	Output membership function for pendulum's angle	103
5.15	Simulink model of inverted-pendulum system with fuzzy	104
	logic control	
5.16	Closed-loop response of cart's position with Fuzzy Logic	105
	controller	
5.17	Closed-loop response of pendulum's angle with Fuzzy	105
	Logic controller	