Werner Leonhard



Control of Electrical Drives

2nd Completely Revised and Enlarged Edition



With 299 Figures

Jürgen-Knorr-Bibliothek Spende der Siemens AG an den FB Elektrotechnik



Table of Contents

1	Elementary Principles of Mechanics					
	1.1	Newto	ons Law	5		
	1.2	Mome	ent of Inertia	7		
	1.3	Effect	of Gearing	9		
	1.4	Power	and Energy	10		
	1.5	Exper	imental Determination of Inertia	11		
2	Dynamics of a Mechanical Drive					
	2.1	Equat	ions Describing the Motion of a Drive with Lumped Inertia	15		
	2.2	Two Axes Drive in Polar Coordinates				
	2.3	Steady State Characteristics of Different Types of Motors and				
		Loads		20		
	2.4	Stable	and Unstable Operating Points	23		
3	Integration of the Simplified Equation of Motion					
	3.1	Soluti	on of the Linearised Equation	27		
		3.1.1	Start of a Motor with Shunt–type Characteristic at No–load	28		
		3.1.2	Starting the Motor with a Load Torque Proportional to			
			Speed	30		
		3.1.3	Loading Transient of the Motor Running at No-load Speed	30		
		3.1.4	Starting of a DC Motor by Sequentially Shortcircuiting			
			Starting Resistors	32		
	3.2	v	tical Solution of Nonlinear Differential Equation	35		
	3.3	Numerical and Graphical Integration				
4	The	Thermal Effects in Electrical Machines				
	4.1	Power	Losses and Temperature Restrictions	41		
	4.2	Heating of a Homogeneous Body				
	4.3	Differe	ent Modes of Operation	45		
		4.3.1	Continuous Duty	46		
		4.3.2	Short Time Intermittent Duty	46		
		4.3.3	Periodic Intermittent Duty	47		

5	Separately Excited DC Machine					
	5.1	Introduction	49			
	5.2	Differential Equations and Block Diagram	52			
	5.3	Steady State Characteristics with Armature and Field Control .	54			
		5.3.1 Armature Control	55			
		5.3.2 Field Control	56			
		5.3.3 Combined Armature and Field Control	58			
	5.4	Dynamic Behaviour of DC Motor at Constant Flux	61			
6	DC Motor with Series Field Winding					
	6.1	Block Diagram of a Series-wound Motor	67			
	6.2	Steady State Characteristics	70			
7	Cont	trol of a Separately Excited DC Machine	75			
	7.1	Introduction	75			
	7.2	Cascade Control of DC Motor in the Armature Control Range .	77			
	7.3	Cascade Control of DC Motor in the Field-weakening Region	87			
	7.4	Supplying a DC Motor from a Rotating Generator	89			
8		ne Static Converter as Power Actuator for DC Drives				
	8.1	Electronic Switching Devices	95			
	8.2	Line-commutated Converter in Single-phase Bridge Connection .	99			
	8.3	Line-commutated Converter in Three-phase Bridge Connection .	115			
	8.4	Line-commutated Converters with Reduced Reactive Power	125			
	8.5	Control Loop Containing an Electronic Power Converter	127			
9		trol of Converter-supplied DC Drives	135			
	9.1	DC Drive with Line-commutated Converter	135			
	9.2	DC Drives with Force-commutated Converters	144			
10	-	metrical Three–Phase AC Machines	155			
		Mathematical Model of a General AC Machine	156			
	10.2	Induction Motor with Sinusoidal Symmetrical Voltages	168			
		10.2.1 Stator Current, Current Locus	168			
		10.2.2 Steady State Torque, Efficiency	173			
			178			
		10.2.4 Starting of the Induction Motor	178			
		Induction Motor with Impressed Voltages of Arbitrary Waveforms 181				
	10.4	Induction Motor with Unsymmetrical Line Voltages in steady State 192				
		10.4.1 Symmetrical Components	192			
		10.4.2 Single–phase Induction Motor	196			
		10.4.3 Single-phase Electric Brake for AC Crane-Drives	198			
		10.4.4 Unsymmetrical Starting Circuit for Induction Motor	200			

15.5 Time-optimal Position Control with Moving Target Point

365

373