Hans Gumhalter

Power Supply in Telecommunications

Third, Completely Revised Edition with 263 Figures and 45 Tables



Contents

1	General and Introduction	1
1.1	Functions and Requirements.	2
1.2	Basic Types of Power Converter	3
1.3	Elements of a Power Converter	4
1.4	Energy Storage	5
1.5	Primary Power Sources.	6
1.6	Power Supply Systems	7
1.6.1	Mains Supply and Standby Power Supply Systems	9
1.6.2	Mains Distribution Switchboards or Mains Switch Panels	9
1.6.3	Central Power Supply.	10
1.6.4	Decentralized Power Supply	12
1.7	UPS Systems	14
1.8	Mains-independent Hybrid Power Supply Systems.	15
1.9	Historical Review	16
2	Requirements of Telecommunications Systems on the Power Supply	20
2.1	D.C. Power Supplies	20
2.1.1	Level of the Direct Voltages	20
2.1.2	Tolerance for Direct Voltages	20
2.1.3	Purity of Direct Voltages.	24
2.1.4	Filter Sections	26
2.1.5	Degree of Radio Interference and Limit Classes	28
2.1.6	Power Distribution System and Voltage Drops.	28
2.1.7	Availability of the Power Supply	29
2.2	A.C. Power Supplies.	31
3	Operating Modes of a Direct Current Power Supply System	32
3.1	Rectifier Mode	32
3.2	Battery (Charge-Discharge) Mode.	32
3.3	Standby Parallel Mode	32
3.3.1	Standby Parallel Mode with Reducing Diodes	
=.=	(Counter electromotive Cells)	37
3.3.2	Standby Parallel Mode with d.c./d.c. Converter	38

ç

.

.

X Contents

3.3.3	Standby Parallel Mode with Compensators for Additional	
	and Counter Voltage	39
3.4	Changeover Mode	40
3.4.1	Changeover Mode with Battery Tap	41
3.4.2	Changeover Mode with Thyristor Contactor	44
3.5	Combined Standby Parallel and Changeover	
	Mode with Compensator for Additional Voltage.	45
3.6	Assignment of Operating Modes to Communications	
	Systems	46
3.7	Further Modes.	49
3.7.1	Changeover Mode with Voltage Gates.	49
3.7.2	Parallel Mode with 'Floating' Charge Method	50
3.7.3	Parallel Mode with Reduced Number of Battery Cells	50
5.1.5	and Compensator	51
3.7.4	Parallel Mode with End Cells	51
5.7.4		51
4	Operating Modes of an Alternating Current Power	
	Supply System	53
4.1	Mains Mode	53
4.2	A.C. Changeover Mode.	53
4.2.1	A.C. Changeover Mode with Interruption $(>1 s)$	53
4.2.2	Standby Power Supply Systems	53
4.2.3	A.C. Changeover Mode with Interruption (<1 s)	57
4.3	Uninterruptible a.c. Changeover Mode.	59
4.3.1	Immediate Standby System	60
4.3.1	Uninterruptible Standby Power Supply System with	00
4.3.2	Rotating Converter	61
4.3.3	Static Standby Power Supply Systems with Inverters Connected	01
4.3.3	to Fail-safe d.c. Power Supplies and with Revert-to-mains Unit	62
4.3.4	Static Standby Power Supply Systems with Inverters Connected	02
4.3.4	to Fail-safe d.c. Power Supplies and without Revert-to-mains	
	••	62
125	Unit	63
4.3.5	Static Uninterruptible Standby Power	()
	Supply Systems.	64
5	Public Mains	69
5.1	Type of Voltage	69
5.2	Tolerances of the a.c. Supply Voltage and Supply Frequency	69
5.2	Wave Shape and Distortion Factor of the a.c.	0)
5.5		70
5 7 1		74
5.3.1	Measures for Reducing Retroactive Effects on the Mains Supply	77
5.4	Power Failures	11
6	Energy Storage	78
6.1	Stationary Lead-Acid Batteries	78
6.1.1	Requirements.	78
0.1.1	Requirements	70

,

6.1.2	Charging and Discharging	78
6.1.3	Open-Circuit Voltage	80
6.1.4	Rated Voltage	81
6.1.5	Discharging Voltage.	81
6.1.6	Self-Discharging	83
6.1.7	Float (Trickle) Charging and Charging Voltage	83
6.1.8	Initial Charging Voltage (Commissioning).	85
6.1.9	Capacity	86
6.1.10	Efficiency and Charging Factor	86
6.1.11	DIN Designation of Battery Type	88
6.1.12	Battery Design	88
6.1.13	Batteries with Tubular Positives.	89
6.1.14	Batteries with Planté Plates (GroE).	93
6.1.15	Comparison of Lead–Acid Batteries	94
6.1.16	Vent Plugs	94
6.1.17	Valve-Regulated Lead-Acid Batteries.	95
6.2	Stationary Alkaline Batteries.	101
6.2.1	Nickel–Cadmium Batteries in Telecommunications	101
6.3	Lithium Primary Batteries	103
6.4	Design Pointers	104
6.4.1	Standby Time (Backup Time)	105
6.4.2	Number of Cells	105
6.4.3	Capacity.	105
6.5		105
6.5.1	Maintenance	113
6.5.2		115
6.5.3	Surveillance of Valve-Regulated Lead-Acid Batteries	115
6.5.4	Battery Monitoring	118
6.5.4 6.5.5	A Statement of the Principle of Battery Service	118
	Battery Inspections	
6.5.6	Capacity Checks	123
6.6	Installation of Batteries	127
7	Basic Circuits and Process Control	129
7.1	Rectifier Circuits	129
7.1.1	Half-wave Rectifier	129
7.1.2	Centre-tap Circuit	129
7.1.3	Bridge Circuit	129
7.1.4	Three-phase Bridge Circuit.	130
7.2	Stabilizing and Control Procedures.	131
7.2.1	Pulse-Sequence Control.	131
7.2.2	Pulse-Width Control	131
7.2.3	Phase Angle Control	132
7.2.4	Distribution and Design of Trigger Pulses.	134
7.3	Rectifying with Stabilization	136
7.3.1	Semi-controlled Single-Phase Bridge Circuit	136
7.3.2	Fully-controlled Three-Phase Bridge Circuit	136
	kully-controlled three-Phase Bridge Lifeuit	

٥

7.4	D.C./D.C. Conversion with Stabilization.	140
7.4.1	D.C. Controller Circuit	140
7.5	Inverting with Stabilization	141
7.5.1	Centre-tap Circuit	142
8	Applications of Control Systems in Power Supply Devices	144
8.1		144
	General	144
8.2	The Operation of Open- and Closed-loop Control Systems	144
8.3	Components of the Closed-loop Control System	146
8.3.1	Final Control Element	146
8.3.2	Controlled Object	147
8.3.3	Control Equipment	147
8.4	Operational Amplifiers in the Regulator	148
8.4.1	Error and Deviation.	150
8.4.2	Classification of Regulators	151
8.5	Controlled Rectifiers with Thyristor Power Section	155
8.5.1	Power Section	155
8.5.2	Control Section	155
8.5.3	Behaviour of the Output Voltage and Dynamic Response	160
8.5.4	Type Designation	161
8.6	Controlled Power Supply Equipment with Transistor	101
0.0	Power Section	162
8.6.1	Rectifiers with Linear Regulators	163
8.6.2	Rectifiers with Switching Regulators	163
8.6.3	Switching-mode Power Supplies.	165
8.6.4	D.C./D.C. Converters	165
8.6.5	Pulse Inverters	172
01010		
9	Switching Mode Power Supplies	176
9.1	Type 48 V/12 A (60 V/10 A)	176
9.1.1	General and Application	176
9.1.2	Modes of Operation.	177
9.1.3	Survey Diagram of the Power Supply System	177
9.1.4	Survey Diagram and Functioning Principle of the Rectifier	
	Module 48 V/12A (60 V/10 A)	178
9.1.5	Technical Data.	180
9.2	Type 48 V (60 V)/30 A and 100 A	181
9.2.1	General and Application	181
9.2.2	Modes of Operation.	182
9.2.3	Survey Diagram of the Power Supply System.	182
9.2.4	Survey Diagram, Block Diagram and Functioning Principle	
	of the Rectifier Module 48 V (60 V)/ 30 A and 100 A	186
9.2.5	Technical Data.	196
-		

.

9.3	Type 48 V/120 A (60 V/100 A)	196
9.3.1	General and Application	196
9.3.2	Modes of Operation.	196
9.3.3	Survey Diagrams of the Power Supply System 400	196
9.3.4	Survey Diagram, Block Diagram and Functioning Principle	
	of the Rectifier Module 48 V/120 A (60 V/100 A)	206
9.3.5	Technical Data.	213
9.4	Type 48 V (60 V, 67 V)/50 A and 100 A	213
9.4.1	General and Application	213
9.4.2	Modes of Operation.	215
9.4.3	Survey Diagram of the Power Supply System	215
9.4.4	Survey Diagram and Functioning Principle of the	
	Rectifier Module 48 V (60 V, 67 V)/50 A and 100 A	215
9.4.5	Technical Data.	217
9.5	Power Supply Controller	220
10	Thyristor Controlled Rectifiers	226
10.1	Type 48 V (60 V)/200 A	226
10.1.1	General and Application	226
10.1.2	Modes of Operation.	226
10.1.3	Survey Diagrams of the Power Supply System	226
10.1.4	Survey Diagram and Functioning Principle of the	
	Rectifier Unit 48 V (60 V)/200 A	228
10.2	Type 48 V (60 V)/1000 A	232
10.2.1	General and Application	232
10.2.2	Modes of Operation.	233
10.2.3	Survey Diagram of the Power Supply System	233
10.2.4	Survey Diagram and Functioning Principle of the Rectifier	
	Unit 48 V (60 V)/1000 A	233
10.3	Assemblies	235
10.3.1	Regulation Module A3	235
10.3.2	Control Module A9	235
10.3.3	Trigger-Pulse Transformer Module A11 (A21)	245
10.3.4	Battery- and Thermo Disconnection Module A16	245
10.3.5	12-Pulse-Regulation Module A23	246
10.4	Technical Data	249
11		250
11	Magnetically Controlled Rectifiers.	250
11.1	Types 24 V to 220 V/10 A to 400 A	250
11.1.1	General and Application	250
11.1.2	Modes of Operation.	251
11.1.3	Survey Diagram of the Power Supply System	251
11.1.4	Survey Diagram and Functioning Principle of the Rectifier	
	Unit 24 V to 220 V/10 A to 400 A	252
11.1.5	Technical Data.	254

ł

Ì

!

12	D.C./D.C. Converter . 25	5
12.1	Type 50 W to 200 W	5
12.1.1	Application	
12.1.1	Modes of Operation	
12.1.2	Survey Diagram and Functioning Principle	-
12.1.9	Technical Data	
12.1.4	Type 750 W. 26 26 26	
12.2.1	Application	
12.2.1	Modes of Operation.	
12.2.2	Survey Diagram and Functioning Principle	
12.2.3	Technical Data	
13	D.C./A.C. Inverters	5
13.1	Type 2.5 kVA	5
13.1.1	Application	5
13.1.2	Type Designation	5
13.1.3	Modes of Operation	6
13.1.4	Survey Diagram of the Power Supply System	6
13.1.5	Survey Diagram, Block Diagram and Functioning Principle of	
	the d.c./a.c. Inverter Module 2.5 kVA	6
13.1.6	Technical Data	2
13.2	Type 15 kVA $(3 \times 5 \text{ kVA})$	2
13.2.1	General and Application	2
13.2.2	Type Designation	3
13.2.3	Modes of Operation	'3
13.2.4	Survey Diagram of the Power Supply System	'3
13.2.5	Survey Diagram and Functioning Principle of the d.c./a.c.	
	Inverter 15 kVA $(3 \times 5 \text{ kVA})$	'3
13.2.6	Technical Data	9
14	Static UPS Systems	
14.1	Type 10 to 500 kVA	30
14.1.1	Application	30
14.1.2	Modes of Operation	30
14.1.3	Overview	
14.1.4	Survey Diagram and Functioning Principle	34
14.1.5	Technical Data) 7
15	Diesel Generating Sets	99
15.1		
13.1	Standby Power Supply System with Fully Automatic Mains Failure Control	າດ
1511		
15.1.1		
15.1.2	Switchgear Control Cubicle	<i>N</i>

15.2	Mains Independent Island Power Supply	
	System with Fully Automatic Alternating Operation	304
15.2.1	Switchgear Control Cubicle	304
15.3	Fully Automatic Electronic Control System.	309
15.4	Fuel Distribution System.	315
15.5	Lubrication Oil Distribution System	315
16	Special Features for Transmission System Power Supplies	316
	•	
16.1	Power Supply for Radio Link Apparatus	316
16.2	Power Supply for Ground Communication Stations	210
	for Telecommunications Satellites.	318
16.3	Mains-Independent Power Supply Systems	322
16.3.1	Primary Power Sources.	322
16.3.2	Solar Power Supply Systems.	329
16.3.3	Passive Cooling System.	334
17	Grounding and Potential Equalization.	337
17.1	Protective Grounding.	337
17.2	Functional Grounding	339
17.3	Functional and Protective Grounding	341
17.4	Selection and Design of Grounds and Grounding	
	Systems	343
17.4.1	Types of Grounds	344
17.4.2	Grounding Main Conductor.	345
17.4.3	Grounding and Potential-Equalization Conductors	345
17.5	Design Pointers for Grounding Systems	349
17.5.1	Specific Ground Resistance.	349
17.5.2	Measurement of Specific Ground Resistance	349
17.5.3	Measurement of Grounding Resistance	350
17.5.4	Calculation of Ground Resistance.	352
17.6	Protection against Overvoltage and Interference	353
17.6.1	Overvoltage Sources.	354
17.6.2	Interference in Telecommunications Systems	355
17.6.3	Design of the Distribution Network for EWSD Systems	357
17.6.4	Design of Grounding, Potential Equalization and Lightning	
	Protection for EWSD Systems.	361
17.6.5	Special Requirements for Lightning Protection in Telecommuni-	
	cations Towers	365
18	Protective Measures	368
18.1	Protection by Disconnection or Indication	372
18.1.1	Protective Measures in the TN Supply System	374
18.1.2	Protective Measures in the TT Supply System	377
18.1.2	Protective Measures in the IT Supply System	378
10.1.5	receive measures in the rr supply system.	210

ç

XVI Contents

.

18.1.4	Fault Current-Operated Protective Circuit	379
18.2	Protection without Disconnection or Indication	381
18.2.1	Protective Insulation	381
18.2.2	Equipment with Protectively Insulated Parts	382
18.2.3	Protective Low Voltage and Functional Low Voltage	383
18.2.4	Protective Separation	384
Bibliography		385
Index.		387

,