CONTENTS

1	HISTORICAL SURVEY AND NEW TRENDS	1
2	DESIGN CONCEPTS OF ON-LOAD TAP-CHANGERS	7
2.1	High-speed Resistor Type OLTC	9
2.1.1	Switching Sequence	12
2.1.2	Duty on Main and Transition Contacts	18
2.1.2.1	Flag Cycle Operation (Non-vacuum and Vacuum Type Diverter Switch)	18
2.1.2.2	Flag Cycle Operation (Non-vacuum Type Selector Switch)	23
2.1.2.3	Symmetrical Pennant Cycle Operation (Non-vacuum and Vacuum Type Diverter Switch)	25
2.1.2.4	Asymmetrical Pennant Cycle Operation	
	(Non-vacuum Type Selector Switch)	
2.1.2.5	Multiple Resistor Cycle Operation (Non-vacuum Type Diverter Switch)	32
2.1.2.6	Vacuum Type Diverter Switch with Two Vacuum Interrupters /	•
	One Transition Resistor (Symmetrical cycle)	38
2.1.2.7	Vacuum Type Diverter Switch with Two Vacuum Interrupters / One Transition Resistor (Asymmetrical Cycle)	48
2.1.2.8	Vacuum Type Diverter Switch with Three Vacuum Interrupters /	
	Two Transition Resistors	
2.2	Reactor Type OLTC	
2.2.1	Switching Sequence	
2.2.1.1	OLTC with Arcing Contacts and Tap Selector	
2.2.1.2	OLTC with Arcing Tap Switch	
2.2.1.3	OLTC with Vacuum Interrupter	
2.2.2	Duty on Switching Contacts	
2.2.2.1	OLTC with Arcing Contacts and Tap Selector	
2.2.2.2	OLTC with Arcing Tap Switch	
2.2.2.3	OLTC with Vacuum Interrupter	
2.3	Tap Selector	
2.3.1	Tap Selectors of In-tank Type OLTCs	
2.3.2	Tap Selectors of Compartment Type OLTCs	78
3	CIRCUITS FOR REGULATING TRANSFORMERS WITH OLTCS	81
3.1	Fundamentals of Regulation	
3.2	Circuits for Regulation at the Neutral End	
3.3	Circuits for Regulation in Delta Connected Windings	
3.4	Circuits for Regulation in Booster Transformers	
3. 5	Circuits for Regulation in Autotransformers	92

4	SELECTION OF OLTCS	98
4.1	Insulation level	102
4.1.1	Internal and External Insulation of OLTCs	102
4.1.2	Voltage Stresses on the Internal OLTC Insulation during	
	Transformer Impulse Testing	
4.1.3	Internal Insulation Distances at Tap Selectors of Different Designs	
4.1.4	Internal Insulation Distance at the Diverter Switch	
4.2	Switching Capability	
4.2.1	Power Factor	
4.2.1.1	Resistor Switching Principle	
4.2.1.2	Reactor Switching Principle	
4.2.2	Permissible Overload of OLTCs in Oil-immersed Power Transformers	
4.2.3	Transition Resistor Layout	
4.2.4	Improvement of the Through-current by Parallel Connection	
4.2.4.1	Diverter Switches Connected in Parallel with Enforced Current Splitting	136
4.2.4.2	Separate OLTCs Connected in Parallel	144
4.3	Potential Connection of the Tap Winding	145
4.3.1	Introduction	145
4.3.2	Calculation of Recovery Voltage and Switched Current	146
4.3.2.1	Regulation with Reversing Change-over Selector	146
4.3.2.1.1	Neutral-end Connection of the OLTC	146
4.3.2.1.2	Delta Connection of the OLTC	150
4.3.2.1.3	OLTCs in Autotransformers	154
4.3.2.1.4	OLTCs in Phase-shifting Transformers	157
4.3.2.1.5	Model for the Calculation of the Recovery Voltages and	
	Switched Currents of Reversing Change-over Selectors	161
4.3.2.2	Regulation with Coarse Change-over Selector	164
4.3.2.2.1	Neutral-end Connection of the OLTC	164
4.3.2.2.2	Delta Connection of the OLTC	168
4.3.2.2.3	Model for the Calculation of the Recovery Voltages and	
	Switched Currents of Coarse Change-over Selectors	171
4.3.3	Methods to Overcome the Recovery Voltage Problem	173
4.3.3.1	Two-way Change-over Selector	174
4.3.3.2	Capacitive Control	176
4.3.3.3	Control Resistors	178
4.4	Leakage Inductance of Coarse/Fine Tap Winding Arrangements	184

CONTENTS

5	SPECIAL APPLICATIONS OF OLTCS	19 5
5.1	Special Designs of OLTCs	195
5.1.1	A-B-C Switching Sequence	195
5.1.2	OLTC for Linear Applications	198
5.1.3	OLTC with Delta-star Change-over Selector	19 9
5.1.4	Multiple Coarse/Fine Tap Winding Arrangements	201
5.1.5	Tap Winding Arrangements with Bias Coil	204
5.2	Phase-shifting Transformers with OLTCs	207
5.2.1	Basic Principle of Phase Angle Regulation	
5.2.2	Single Core Designs (Direct Regulation at the Line End)	212
5.2.2.1	Circuitry	
5.2.2.2	Selection of the OLTC	
5.2.3	Dual Core Designs (Regulation with Series and Exciting Unit)	220
5.2.3.1	Circuitry	
5.2. 3 .2	Selection of the OLTC	226
5.2.4	Independent Variations of Phase Angle and In-phase Voltage Magnitude	228
5.3	HVDC Converter Transformers	231
5.4	Reactors with OLTCs	234
5.4.1	Basic Considerations about the Breaking Stresses	236
5.4.2	Current Limiting Reactor Application (Load-independent Current)	240
5.4.3	Shunt Reactor Application (Load-independent Voltage)	
5.5	Parallel Operation of Transformers	
5.5.1	Load Distribution of Paralleled Transformers	
5.5.2	Out-of-step Condition of Transformers Connected in Parallel	249
	BIBLIOGRAPHY	255