



Technology Training that Works

Practical Medium & High Voltage Testing of Electrical Equipment for Engineers and Technicians

Contents

Preface

1	Introduction	1
1.1	Electrical system	1
1.2	HV AND MV equipment	2
	1.2.1 Voltage Classification	3
1.3	Use of HV and MV equipment	4
	1.3.1 High voltage equipment	4
	1.3.2 Medium voltage equipment	4
	1.3.3 Common HV and MV equipment	5
1.4	Need for testing	5
1.5	Purpose of testing	6
1.6	Categories of tests	6
1.7	Variations to test voltages and results	7
	1.7.1 Altitudes above sea level	7
	1.7.2 Temperature conditions	8
	1.7.3 Tolerances	8
2	Insulation testing	9
2.1	Need for insulation	9
2.2	Principles of insulation testing	10
	2.2.1 Capacitive current (I_c)	11
	2.2.2 Dielectric absorption current (I_{da})	11
	2.2.3 Resistive (leakage) current (I_r)	11
2.3	Purpose of insulation testing	13
2.4	Testing the insulation of equipment	14
2.5	Insulation resistance test voltages	15
2.6	Types of testers	16



Technology Training that Works

2.7	Construction of a tester	16
2.8	Connecting a tester	16
2.9	Test procedure	18
2.10	Precautions to be taken when measuring insulation	21
2.11	Polarization index	22
2.12	Step voltage test	23
2.13	Readings and interpretation	24
2.14	Dryness of insulation using absorption ratio	25
<hr/>		
3	High potential tests	29
<hr/>		
3.1	Purpose of hi-pot testing	29
3.1.1	AC high potential testing (also called an over-potential test)	29
3.1.2	Power factor testing	29
3.1.3	AC hertz test	29
3.1.4	Resonant test	30
3.2	AC and DC hi-pot tests	30
3.3	Test equipment construction and connections	31
3.4	Safety precautions to be taken	32
3.5	Test voltages as per applicable standards	33
<hr/>		
4	Oil testing	35
<hr/>		
4.1	Transformer oil – dielectric properties and uses	35
4.2	The need for testing transformer oil	36
4.3	Dielectric test	37
4.4	Improvement of oil by filtration	38
4.5	Oil filtration units	40
4.6	Test of acidity	43
4.7	Other tests	43
4.7.1	Interfacial tension test (IFT)	43
4.7.2	Color	44
4.7.3	Relative density	45
4.7.4	Dielectric dissipation factor	45
4.7.5	Water content	45
4.7.6	Flash point	45
4.7.7	Viscosity	46
4.7.8	Pour point	46
4.7.9	Specific resistance	46
4.8	Dissolved gas analysis	46
4.8.1	Features and importance	46



Technology Training that Works

4.8.2	Basic gas analysis inferences	47
4.8.3	DGA study methods	48
4.8.4	DGA case studies	50
4.9	Precautions to be taken when sampling oil	54
5	Testing of transformers	65
5.1	General	65
5.2	Routine tests	66
5.3	Guarantees and tolerances	67
5.4	Visual inspection	67
5.5	Winding resistance measurements	68
5.6	Turns ratio measurement	68
5.7	Polarity and vector group check	69
5.8	Impedance voltage and load losses	71
5.9	No load losses and current measurement	72
5.10	Insulation resistance tests	72
5.11	Dielectric tests	73
5.12	RIV Corona measurements	74
5.13	Partial discharge measurements	75
5.14	Impulse tests	75
5.15	Tests on OLTC	76
5.16	Type tests	77
5.17	Special tests	77
5.17.1	Measurement of zero sequence impedance	77
5.17.2	Short circuit test	78
5.17.3	Other special tests	78
5.18	Tests on bushings	78
5.18.1	Main insulation (C_1) test connections	79
5.18.2	Test procedure	79
5.18.3	Test results and inference	79
5.18.4	Hot collar test	79
5.18.5	Test connections	80
5.18.6	Test procedure	80
5.18.7	Test results	80
5.18.8	Other tests on bushings	80
6	CT testing	81
6.1	Instrument transformers	81
6.2	Current transformer types	82



Technology Training that Works

6.3	Burden and accuracy classes	85
6.4	Other technical parameters	87
6.5	Polarity	89
6.6	Magnetization curve	89
6.7	Metering and protection CT requirements	90
6.8	Major tests on a CT	92
6.8.1	Type tests	92
6.8.2	Routine tests	92
6.8.3	Special tests	93
6.9	Test procedures	93
6.9.1	Short time current I_{th} withstand test	93
6.9.2	Temperature rise test	93
6.9.3	Impulse tests	93
6.9.4	RIV test	95
6.9.5	Partial discharge test	96
6.9.6	PF voltage tests	96
6.9.7	Inter-turn over-voltage test	96
6.9.8	Chopped impulse test on primary winding	96
6.9.9	Capacitance and dielectric dissipation factor	97
6.9.10	Transmitted over voltages measurement	97
6.9.11	Ratio verification test	98
6.9.12	Accuracy class verification	98
6.9.13	Polarity test	98
6.9.14	Test for CT magnetizing curve	98
6.9.15	Short circuit test	100
6.10	Safety precautions	100
<hr/>		
7	VT testing	101
<hr/>		
7.1	Types of voltage transformers	101
7.2	Basic technical terms	103
7.3	Connection of voltage transformers	105
7.4	Tests on voltage transformers	107
7.4.1	Type tests	107
7.4.2	Routine tests	107
7.4.3	Special tests	107
7.5	Test procedures	107
7.5.1	Temperature rise test	107
7.5.2	Short-circuit withstand capability test	109
7.5.3	Impulse test on primary winding	109
7.5.4	Lightning impulse test	109
7.5.5	Switching impulse test	111
7.5.6	Wet test for outdoor type transformers	111



Technology Training that Works

7.5.7	RIV test	111
7.5.8	Power frequency withstand test	112
7.5.9	Partial discharge test	112
7.5.10	Chopped impulse test on primary winding	113
7.5.11	Capacitance and dielectric dissipation factor	113
7.5.12	Transmitted over voltages measurement	113
7.5.13	Ratio and accuracy class verification test	114
<hr/>		
8	Ducter testing	115
<hr/>		
8.1	Need for the instrument	115
8.2	Description of instrument	115
8.3	Working principle	116
8.3.1	Kelvin bridge	116
8.3.2	Wheatstone bridge	117
8.3.3	Four wire instrument	118
8.4	Milli-ohmmeter vs micro-ohmmeter	120
8.5	Breaker contact resistance measurement	121
8.6	Transformer resistance measurement	121
8.7	Precautions during measurements	123
<hr/>		
9	Tests on other major equipment	125
<hr/>		
9.1	Other major equipment	125
9.2	HV/MV switchgear and breakers	125
9.2.1	Routine tests	125
9.2.2	Type tests	126
9.2.3	Lightning impulse voltage tests	126
9.2.4	Power-frequency voltage tests	126
9.2.5	Testing for internal faults	128
9.3	MV motors	131
9.4	MV capacitors	132
9.4.1	Routine tests	132
9.4.2	Type tests	132
9.4.3	Test procedures	132
9.5	Disconnectors	133
9.5.1	Type tests	133
9.5.2	Routine tests	134
9.5.3	Procedures	134



Technology Training that Works

10	Field tests	135
10.1	Need for field tests	135
10.2	General safety procedures	136
10.2.1	Basic precautions	136
10.2.2	Test area safety practices	137
10.2.3	Control and measurement circuits	137
10.2.4	Grounding and shorting	137
10.2.5	Spacing	138
10.2.6	High-power testing	138
10.2.7	General	138
10.3	Transformers	139
10.3.1	Visual and mechanical inspection	139
10.3.2	Electrical tests	139
10.3.3	Acceptance criteria	140
10.4	Switchgear	140
10.4.1	Visual and mechanical inspection	140
10.4.2	Electrical tests	141
10.4.3	Acceptance criteria	141
10.5	High voltage disconnectors	141
10.5.1	Visual and mechanical checks	141
10.5.2	Electrical checks	141
10.5.3	Test values	141
10.6	MV cables	141
10.6.1	Visual and mechanical inspection	141
10.6.2	Electrical tests	142
10.6.3	Acceptance criteria	142
10.7	MV bus ducts	142
10.7.1	Visual and mechanical inspection	142
10.7.2	Electrical tests	143
10.7.3	Acceptance criteria	143
10.8	Instrument transformers	143
10.8.1	Visual and mechanical inspection	143
10.8.2	Electrical tests	143
10.8.3	Acceptance criteria	143
10.9	Rotating machinery	144
10.9.1	Visual and mechanical inspection	144
10.9.2	Electrical tests	144
10.9.3	Acceptance criteria	144
10.10	Surge arresters	144
10.10.1	Visual and mechanical inspection	144
10.10.2	Electrical tests	144
10.10.3	Acceptance criteria	144



Technology Training that Works

10.11	Outdoor bus structures	145
10.11.1	Visual and mechanical inspection	145
10.11.2	Electrical tests	145
10.11.3	Acceptance criteria	145
10.12	Engine generators	145
10.12.1	Visual and mechanical inspection	145
10.12.2	Electrical tests	145
10.12.3	Acceptance criteria	145
10.13	Maintenance tests	145
10.13.1	Multiplication factors	146
10.13.2	Recommended schedule	146
<hr/> Appendices		149