

LIST OF FIGURES

Fig. No.	Description	Page No.
1.1	Flow Chart of Designing of Grounding System	11
1.2	Four Point Method of Resistivity Measurement.....	13
1.3	Wenner Method & Schlumberger-Palmer Method	14
1.4	Resistivity Measurement in the Field (220kV SMB)	16
1.5	Resistivity Measurement in the Field (220kV NARELA).....	16
1.6	Resistance value shown by Earth Tester(WACO – MAKE).....	17
1.7	Resistance value shown by Earth Tester(WACO – MAKE).....	17
2.1	High Voltage Gas Insulated Substation.....	23
2.2	Air Insulated Substation Switchyard with Gravel Surface	23
2.3	Flow of Current Through the Body of Working Staff During Fault.....	25
2.4	Different Resistances of Circuit for Touch Voltage	25
2.5	Thevenin Equivalent of Circuit for Touch Voltage.....	26
2.6	Different Resistances of Circuit for Step Voltage	27
2.7	Thevenin Equivalent of Circuit for Step Voltage	27
2.8	Concept of Voltage Gradient	30
2.9	Six Dangerous Voltages in Substation	31
2.10	Fault Current & Max Grid Current in Substation.....	32
2.11	Touch Potential and Step Potential.....	34
2.12	Possible Touch Potential in Case of GIS.....	35
2.13	Potential Gradient for Step And Touch Potential	35
2.14	Actual Grounding of GIS	36
2.15	Grounding Mat of The Substation	37
2.16	Actual View of GIS Substation	38
2.17	Typical Fault Condition in GIS	40
2.18	Enclosure Current in GIS	41

2.19	Grounding of GIS Enclosures -1	42
2.20	Grounding of GIS Enclosures -2	43
3.1	Impact of Salt, Moisture & Temperature on Soil Resistance	46
3.2	Soil Resistivity Vs. Electrode Separation Curve	48
3.3	Different Component of Grounding Resistance	49
3.4	Two Layer Soil Model.....	50
3.5	Flow of Current During Fault	56
3.6	MATLAB GUI- Grounding Design	59
3.7	MATLAB GUI- Soil Modeling	61
3.8	Uniform Soil Model Module of RPDGS- Case 1	64
3.9	Two Layer Soil Model Module of RPDGS- Case 1	64
3.10	Uniform Soil Model Module of RPDGS- Case 2.....	65
3.11	Two Layer Soil Model Module of RPDGS- Case 2.....	65
3.12	Uniform Soil Model Module of RPDGS- Case 3.....	66
3.13	Two Layer Soil Model Module of RPDGS- Case 3.....	66
3.14	Uniform Soil Model Module of RPDGS- Case 4.....	67
3.15	Two Layer Soil Model Module of RPDGS- Case 4.....	67
3.16	Uniform Soil Model Module of RPDGS- Case 5.....	68
3.17	Two Layer Soil Model Module of RPDGS- Case 5.....	68
3.18	Uniform Soil Model Module of RPDGS- Case 6.....	69
3.19	Two Layer Soil Model Module of RPDGS- Case 6.....	69
4.1	(a) GPR Computation by Autogrid Software, (b) Step Potential Plot by Autogrid Software, (c) Touch Potential Plot by Autogrid Software - Case 1-----	77
4.2	Complete Design of RPDGS Case-1 (a)Unsafe , (b) Safe	78
4.3	a) GPR Computation by Autogrid Software, (b) Step Potential Plot by Autogrid Software, (c) Touch Potential Plot by Autogrid Software - Case 2-----	79
4.4	Complete Design of RPDGS Case-2 (a)Unsafe , (b) Safe	80

4.5	a) GPR Computation by Autogrid Software, (b) Step Potential Plot by Autogrid Software, (c) Touch Potential Plot by Autogrid Software - Case 3-----	81
4.6	Complete Design of RPDGS Case-3 (a)Unsafe , (b) Safe	82
4.7	a) GPR Computation by Autogrid Software, (b) Step Potential Plot by Autogrid Software, (c) Touch Potential Plot by Autogrid Software - Case 4 -----	83
4.8	Complete Design of RPDGS Case-4 (a)Unsafe , (b) Safe	84
4.9	a) GPR Computation by Autogrid Software, (b) Step Potential Plot by Autogrid Software, (c) Touch Potential Plot by Autogrid Software - Case 5 -----	85
4.10	Complete Design of RPDGS Case-5 (a)Unsafe , (b) Safe	86
4.11	a) GPR Computation by Autogrid Software, (b) Step Potential Plot by Autogrid Software, (c) Touch Potential Plot by Autogrid Software - Case 6 -----	87
4.12	Complete Design of RPDGSCase-6 (a)Unsafe , (b) Safe	88
4.13	Basic of Resistance of Any Conductor.....	91
4.14	Basic of Resistance of Strip or Rod.....	91
4.15	Measurement of Resistivity Of Water	92
4.16	Circuit Diagram for ESP Calculation of One Rod	92
4.17	ESP Calculation for Earth Mat (Uniform Soil Model).....	93
4.18	ESP Calculation for Earth Mat (Two Layer Soil Model).....	93
4.19	Experimental Setup Preparation	94
4.20	Experimental Setup for Water Resistivity Measurement	94
4.21	Voltage Measurement Location for Experiment	95
4.22	Experimental Setup for ESP Measurement for Uniform Layer Model.....	95
4.23	Measurement of Values for Uniform Layer Model.....	96
4.24	ESP Distribution Graph (1)	97
4.25	ESP Distribution Graph (2)	100
4.26	ESP Distribution Graph (3)	101

4.27	ESP Distribution Graph (3).....	112
4.28	ESP Calculation/Measurement (Two Layer Soil Model)-1	102
4.29	ESP Calculation/Measurement (Two Layer Soil Model)-2	102
5.1	Soil Resistivity Vs. Resistance	107
5.2	Soil Resistivity Vs. Safe Potentials	108
5.3	Height Of Gravel Vs. Safe Potentials	108
5.4	Surface Material Resistivity Vs. Safe Potentials	109
5.5	Ground Grid Depth Vs. Actual Potentials	110
5.6	Fault Current Vs. GPR.....	111
5.7	Fault Current Vs. Actual Potentials.....	111
5.8	Conductor Spacing Vs. Actual Potentials.....	112
5.9	Two Layer Soil Model.....	112
5.10	Uniform Vs. Two Layers (Positive 'K' Case).....	114
5.11	Uniform Vs. Two Layers (Negative 'K' Case)	115