

Contents

1	How a Substation Happens	<i>James C. Burke and Anne-Marie Sahazizian</i>	
1.1	Background		1-1
1.2	Needs Determination		1-2
1.3	Budgeting		1-2
1.4	Financing		1-2
1.5	Traditional and Innovative Substation Design		1-2
1.6	Site Acquisition		1-3
1.7	Design, Construction, and Commissioning Process		1-3
2	Gas-Insulated Substations	<i>Philip Bolin</i>	
2.1	SF ₆		2-1
2.2	Construction and Service Life		2-2
2.3	Economics of GIS		2-17
3	Air-Insulated Substations — Bus/Switching Configurations	<i>Michael J. Bio</i>	
3.1	Single Bus (Figure 3.1)		3-1
3.2	Double Bus, Double Breaker (Figure 3.2)		3-2
3.3	Main and Transfer Bus (Figure 3.3)		3-2
3.4	Double Bus, Single Breaker (Figure 3.4)		3-3
3.5	Ring Bus (Figure 3.5)		3-4
3.6	Breaker-and-a-Half (Figure 3.6)		3-5
3.7	Comparison of Configurations		3-5
4	High-Voltage Switching Equipment	<i>David L. Harris</i>	
4.1	Ambient Conditions		4-1
4.2	Disconnect Switches		4-1
4.3	Load Break Switches		4-2
4.4	High-Speed Grounding Switches		4-2
4.5	Power Fuses		4-3
4.6	Circuit Switchers		4-3
4.7	Circuit Breakers		4-4
4.8	GIS Substations		4-6
4.9	Environmental Concerns		4-6

5	High-Voltage Power Electronic Substations	<i>Gerhard Juette and Asok Mukherjee</i>	
5.1	Converter Stations (HVDC).....		5-2
5.2	FACTS Controllers.....		5-5
5.3	Control and Protection System.....		5-10
5.4	Losses and Cooling.....		5-16
5.5	Civil Works.....		5-16
5.6	Reliability and Availability.....		5-17
5.7	Future Trends.....		5-18
6	The Interface between Automation and the Substation	<i>James W. Evans</i>	
6.1	Introduction.....		6-1
6.2	Physical Considerations.....		6-2
6.3	Analog Data Acquisition.....		6-4
6.4	Status Monitoring.....		6-10
6.5	Control Functions.....		6-11
6.6	Communications Networks inside the Substation.....		6-14
6.7	Testing Automation Systems.....		6-17
6.8	Summary.....		6-20
7	Substation Integration and Automation	<i>John D. McDonald</i>	
7.1	Introduction.....		7-1
7.2	Definitions and Terminology.....		7-2
7.3	Open Systems.....		7-2
7.4	Architecture Functional Data Paths.....		7-3
7.5	Substation Integration and Automation System Functional Architecture.....		7-3
7.6	New vs. Existing Substations.....		7-3
7.7	Equipment Condition Monitoring.....		7-4
7.8	Substation Integration and Automation Technical Issues.....		7-5
7.9	Protocol Fundamentals.....		7-13
7.10	Protocol Considerations.....		7-14
7.11	Choosing the Right Protocol.....		7-17
7.12	Communication Protocol Application Areas.....		7-17
7.13	Summary.....		7-18
8	Oil Containment	<i>Anne-Marie Sahazizian and Tibor Kertesz</i>	
8.1	Oil-Filled Equipment in Substation [IEEE 980-1994 (R2001)].....		8-2
8.2	Spill Risk Assessment.....		8-3
8.3	Containment Selection Consideration [IEEE 980-1994 (R2001)].....		8-4
8.4	Oil Spill Prevention Techniques.....		8-5

9	Community Considerations	<i>James H. Sosinski</i>	
9.1	Community Acceptance		9-1
9.2	Planning Strategies and Design		9-2
9.3	Permitting Process		9-10
9.4	Construction		9-11
9.5	Operations		9-12
9.6	Defining Terms (IEEE, 1998)		9-13
10	Animal Deterrents/Security	<i>C.M. Mike Stine and Sheila Frasier</i>	
10.1	Animal Types.....		10-2
10.2	Mitigation Methods		10-3
11	Substation Grounding	<i>Richard P. Keil</i>	
11.1	Reasons for Substation Grounding System		11-1
11.2	Accidental Ground Circuit		11-2
11.3	Design Criteria		11-8
12	Grounding and Lightning	<i>Robert S. Nowell</i>	
12.1	Lightning Stroke Protection		12-1
12.2	Lightning Parameters.....		12-2
12.3	Empirical Design Methods		12-5
12.4	The Electrogeometric Model (EGM)		12-7
12.5	Calculation of Failure Probability		12-18
12.6	Active Lightning Terminals		12-20
13	Seismic Considerations	<i>R.P. Stewart, Rulon Fronk, and Tonia Jurbin</i>	
13.1	Historical Perspective		13-1
13.2	IEEE 693 — a Solution		13-1
13.3	Relationship between Earthquakes and Substations		13-2
13.4	Applicable Documents.....		13-2
13.5	Decision Process for Seismic Design Considerations		13-3
13.6	Performance Levels and Required Spectra		13-3
13.7	Qualification Process		13-10
14	Substation Fire Protection	<i>Don Delcourt</i>	
14.1	Fire Hazards		14-1
14.2	Fire Protection Measures.....		14-4
14.3	Fire Protection Selection.....		14-5
14.4	Conclusion		14-7
	Substation Control Building Fire-Protection-Review Checklist.....		14-8
	Substation Switchyard Fire Protection Assessment Process		14-9

15	Substation Communications	<i>Daniel E. Nordell</i>	
15.1	Introduction		15-1
15.2	Supervisory Control and Data Acquisition (SCADA) Historical Perspective		15-2
15.3	SCADA Functional Requirements		15-4
15.4	SCADA Communication Requirements.....		15-4
15.5	Components of a SCADA System		15-5
15.6	SCADA Communication Protocols: Past, Present, and Future		15-6
15.7	The Structure of a SCADA Communications Protocol.....		15-9
15.8	Security for Substation Communications		15-11
15.9	Electromagnetic Environment		15-14
15.10	Communications Media.....		15-15
15.11	Additional Information		15-22
16	Physical Security	<i>John Oglevie and Pat Rooney</i>	
16.1	Introduction		16-1
16.2	History		16-2
16.3	Types of Intruders.....		16-3
16.4	Substation Development		16-4
16.5	Security Methods		16-5
16.6	Security Assessment		16-11
17	Cyber Security of Substation Control and Diagnostic Systems	<i>Joseph Weiss and Martin Delson</i>	
17.1	Introduction		17-1
17.2	Definitions and Terminology.....		17-2
17.3	Threats to the Security of Substation Systems.....		17-3
17.4	Substation Automation (SA) System Vulnerabilities.....		17-4
17.5	Measures to Enhance Cyber Security.....		17-6
17.6	Devising a Security Policy.....		17-11
17.7	Future Measures.....		17-12
18	Gas-Insulated Transmission Line (GIL)	<i>Hermann Koch</i>	
18.1	Introduction		18-1
18.2	History		18-2
18.3	System Design		18-3
18.4	Development and Prototypes.....		18-9
18.5	Advantages of GIL.....		18-21
18.6	Application of Second-Generation GIL.....		18-25
18.7	Quality Control and Diagnostic Tools.....		18-27
18.8	Corrosion Protection		18-28
18.9	Voltage Stress Coming from the Electric Power Net		18-30
18.10	Future Needs of High-Power Interconnections.....		18-32