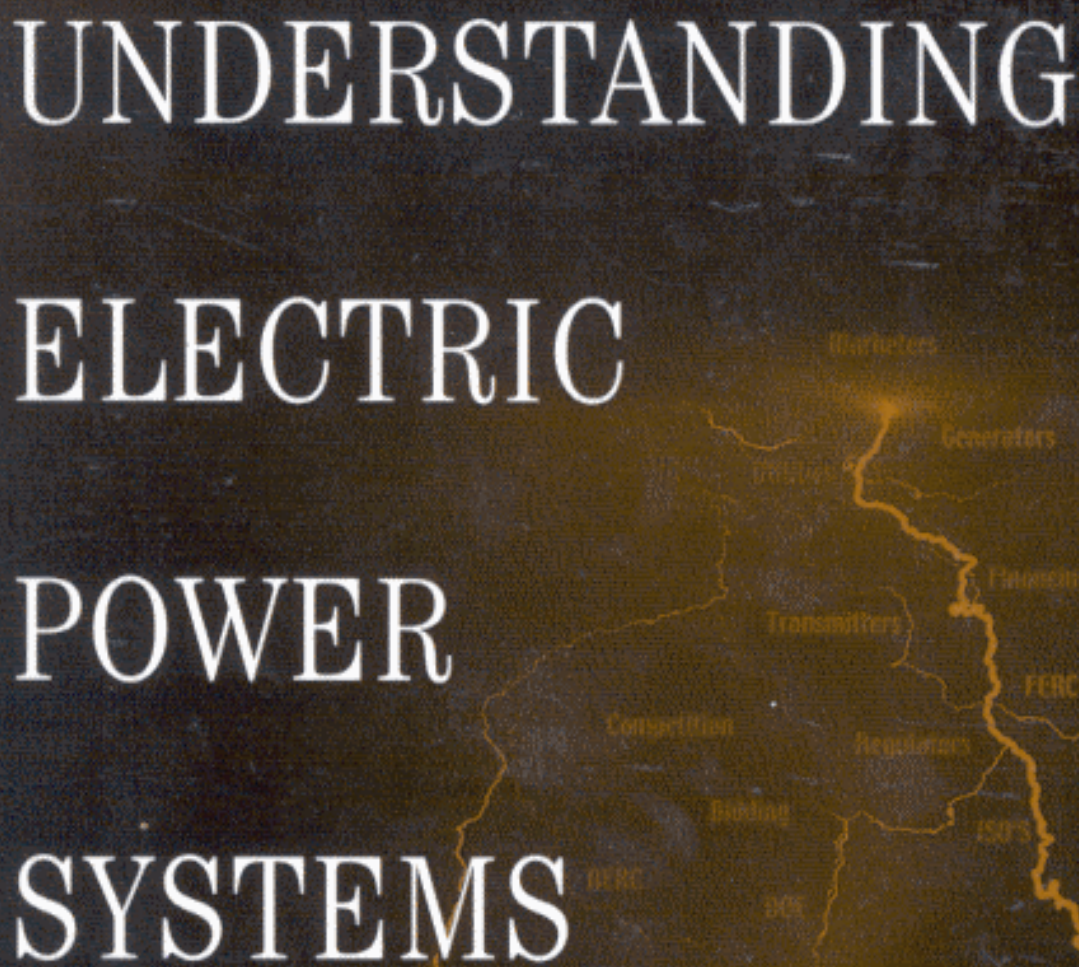


UNDERSTANDING ELECTRIC POWER SYSTEMS



**An Overview of the Technology
and the Marketplace**

Jack Casazza and Frank Delea

CONTENTS

List of Figures	xv
Preface	xvii
1 History of Electric Power Industry	1
Origin of the Industry / 1	
Development of the National Electric Power Grid / 3	
Industry Ownership Structure / 6	
Legislation and Regulation / 8	
Blackouts and the Reliability Crisis / 8	
Environmental Crisis—The Shift to Low-Sulfur Oil / 9	
Fuel Crisis—The Shift from Oil / 9	
Financial Crisis / 9	
Legislative and Regulatory Crisis / 10	
2 Electric Power System	13
Customers / 14	
Sources of the Electric Energy—Generation / 15	
Delivery System / 17	
Interconnections / 19	
Grid / 21	
3 Basic Electric Power Concepts	23
Electric Energy / 24	
Concepts Relating to the Flow of Electricity / 26	
Direct Current / 27	
Alternating Current / 27	
Three Phases / 29	
Synchronism / 29	

Characteristics of AC Systems / 29

Resistance / 29

Induction and Inductive Reactance / 30

Inductive Reactance / 30

Capacitance and Capacitive Reactance / 30

Capacitive Reactance / 31

Reactance / 31

Impedance / 31

Ohm's Law for Alternating Current / 33

Power in Alternating Current Circuits / 33

Real Power / 34

Reactive Power / 34

Advantages of AC over DC Operation / 35**Transformers / 36****Power Flow / 37**

Division of Power Flow Among Transmission Lines / 37

Voltage Drop and Reactive Power Flow / 37

Power Flow and Phase Angle Differences / 37

Stability / 38**Results of Instability / 40****4 Electric Energy Consumption****41**

End-Uses for Electricity / 41

Customer Classes / 42

Rate Classes / 43

Demand and Energy / 44

Energy / 44

Effects of Load Diversity / 45

System Load / 47

Load Management / 48

Reactive Power / 50

Forecasts / 50

Losses and Unaccounted-for Energy in the Delivery System / 52

5 Electric Power—Generation**55**

Types of Generation / 56

Steam Turbines / 56

Combustion (Gas) Turbines / 57

Hydro Turbines / 57

Pumped Storage / 58

Nuclear Units / 58

Reciprocating Engines / 58

Micro Turbines / 58

Other Forms of Generation / 59

Characteristics of Generating Plants / 60

Size / 62

Efficiency / 64

Availability / 65

Capital Cost of Generation / 66

Type of Use / 66

Life Extension / 67

Synchronous Generators / 67

Resource Procurement / 68

Fuel Measurements / 69

Fuel Transportation / 70

Fuel Used / 70

Fuel Purchasing / 71

Emission Rights / 71

6 Technology of the Electric Transmission System

73

Components / 73

HVAC / 74

Overhead / 74

Ratings / 74

Cable / 75

Submarine Cables / 76

Substations / 76

Substation Equipment / 77

Substation Breaker Arrangements / 81

Transmission System Aging / 82

HVDC / 82

Advantages of HVDC / 83

Disadvantages of HVDC / 84

Knowledge Required of Transmission System / 84

7 Distribution

85

Primary Feeders / 86

Radial Systems / 86

Loop Systems / 87

Primary Network Systems / 87

Distribution Transformers / 87

Secondary Systems / 87

Distribution Capacity / 89

- Losses / 90
- Ratings / 90
- Metering / 90
- Control of Voltage / 91
 - Capacitors / 91
 - Voltage Regulators / 92
- Reliability / 92
 - Quality of Service / 93
- Design of Distribution Systems / 93
- Distributed Generation / 94
- Operation of Distribution Systems / 94

8 Functioning of the Electric Bulk Power System **97**

- Coordination / 97
- Operation / 99
 - Control Areas / 99
 - Operating Reserves / 102
 - Ancillary Services / 102
 - Emergencies / 103
 - Operating Emergencies / 104
- Parallel Path Flow and Loop Flow / 105
- Power Transfer Limits / 105
 - Determination of Total Transfer Capability / 106
 - Reduction of Power Transfers—Congestion Management / 107
- Planning / 107
- Planning Standards / 108
 - Generation Planning / 108
 - Least Cost Planning / 110
 - Transmission Planning / 110
 - Load-Flow Studies* / 112
 - Stability Studies* / 112
 - Short-Circuit Duty Studies* / 112
- New Planning Environment / 113

9 Reliability **117**

- Costs of Power Outages / 119
- Ways to Measure Reliability / 120
- Planning and Operating a Reliable and Adequate Power System / 121
 - Transmission Security and Security Coordinators / 122
 - Paying for Extra Reliability / 124
 - Compliance / 124

Generation / 125	
Transmission / 126	
Transmission System Problems / 126	
Planning and Operating Standards / 127	
Voltage and Reactive Control / 128	
Distribution / 129	
Summary / 129	

10 Restructuring, Competition and Deregulation 131

Causes of Restructuring / 131
Types of Restructuring / 132
Effects of Restructuring / 133
Six Networks / 133
Changing Customer Requirements / 135

11 Legislation and Regulation—The Regulatory Network 137

Pricing and Regulation / 137
Federal Legislation / 138
Public Utility Holding Company Act of 1935 / 138
Federal Power Act / 139
Other Federal Laws / 140
Environmental Laws / 140
Department of Energy Organization Act / 141
PURPA / 142
Energy Policy Act (“EPACT”) of 1992 / 144
<i>PUHCA Modifications</i> / 144
<i>FPA Modifications</i> / 144
Federal Regulatory Agencies / 145
FERC / 145
SEC / 146
Environmental Protection Agency (EPA) / 146
Department of Energy (DOE) / 147
Federal Legislation Under Consideration / 147
State Regulatory Authority / 148
Recent Federal Regulation Impacting the Electric Industry / 148
Orders 888 and 889 / 148
Order 2000 / 150
Tariff Basis / 151
Transmission Rights / 151

Physical Transmission Rights / 151

Financial Transmission Rights / 152

Average System versus Incremental Costs / 152

State Regulation / 153

Customer Choice / 153

Metering / 154

Distribution Rates / 154

State and Local Environmental Requirements / 155

Overall Regulatory Problems / 155

12 The Business Network 157

Investment and Cost Recovery / 157

Changing Industry Structure / 158

Utility Responses / 158

Holding Company Formation / 158

Unbundling / 159

New Structure / 160

Power Producers / 160

Power Plant Divestitures / 160

Transmitters / 162

Development of Non-Regulated Power Market / 163

Distributors / 163

Marketers / 164

Wheeling and Customer Choice / 164

Contracts and Agreements / 165

13 ISOs, RTOs and ITPs 167

ISO Formation / 167

Functions of ISOs / 168

Regional Operating Functions / 168

Regional Planning Functions / 169

RTOs / 169

14 The Money Network 171

Allocation of Costs and Economic Benefits / 172

Average Costs Versus Incremental Costs / 173

Market Versus Operational Control / 173

Market Power Issues / 173

Price Caps / 173

Standard Market Design (SMD) / 174

Objectives and Goals / 174

Proposals / 174

Transmission Owner's Options / 175

Independent Transmission Providers (ITPs) / 175

Transmission Charges / 176

Wholesale Electric Market Design / 177

Locational Marginal Pricing (LMP) / 177

Resource Adequacy / 178

Transmission Tariffs / 179

Merchant Transmission / 179

Markets for Buying and Selling Rights / 179

15 Information, Communications and Control Network 181

Financial and Business Operations / 182

System Operations / 182

Distribution Operations / 183

Physical Security / 184

Commercial Security / 184

16 Role of NERC, NAESB and Other Organizations 187

NERC, Reliability Councils, and RTOs / 188

NAESB / 188

Enforcement and Dispute Resolution / 188

Professional Organizations / 189

IEEE / 189

CIGRE / 190

Industry Associations / 190

NARUC / 190

AEIC / 190

APPA / 191

EEI / 191

ELCON / 192

NRECA / 192

Electric Power Supply Association / 193

Research Organizations / 193

EPRI / 193

Other Research / 194

NRRI / 194

17	Where Restructuring Stands	195
	Required Additional Analyses / 197	
	Abandonment of Deregulation / 197	
	Power Supply / 197	
	2002 / 197	
	The Future / 197	
	<i>Energy Trading</i> / 198	
	Reliability Concerns / 198	
	Transmission Problems / 198	
	National Power Survey / 198	
	Conclusions / 199	
	Index	201
	About the Authors	211