

Index

Page references followed by t indicate material in tables.

A

AC transmission lines, in grid, 58–59. *See also* Alternating current (AC)

Advance planning, grid reliability via, 64

Agencies, in long-term utility planning, 123, 125. *See also* California entries; Federal entries; National Electricity Reliability Council (NERC)

Air, in combustion turbines, 34–35, 35–36

Alternating current (AC). *See also* AC transmission lines

- from generator, 50–51
- grid and, 49, 51, 52–53, 54, 55, 56

Ampere, 11

Ancillary service (AS) bids, 187, 188–189

Ancillary service markets, day-ahead supply bidding into, 165

Ancillary service penalties, 204

Ancillary service requirements

- day-ahead demand forecasting of, 84, 89
- day-ahead setting of, 164–165
- reliability concerns and, 162

Ancillary service rights, 205

Ancillary services forecasting, day-ahead, 83

Ancillary service suppliers

- in California short-term energy market, 285–286
- California versus PJM, 288–290
- determining, 165–166

Annual demand changes, in long-term planning, 129–131

Annual load shapes, 19–20

- in long-term planning, 130–131

Appliances, reactive and resistive elements in, 56

Area control error (ACE), as control group responsibility, 76

Asset management

- for electric power delivery, 5
- in short-term markets, 180–191

August 14, 2003 power blackout, 76–80

Automatic generation control (AGC), 165, 167

- in grids, 57–58, 70

Availability (Av), in risk assessment, 264–265

B

Banks, long-term market design and, 171–172

Baseload CCGT units, least-cost dispatch for, 109–110

Baseload coal units, optimization using marginal costs for, 103–108

Baseload unit, 258, 259

- forced outages and, 263–264

Bearing failures, in steam generating plant operations, 27

Bidding. *See* Competitive bidding; Demand bidding; Load bids; Optimal bidding; Schedule adjustment bidding; Standard bidding; Supply bidding

Blackouts, in maintaining system stability, 74. *See also* August 14, 2003 power blackout

Black–Scholes formula, 210

Black start capability, grid reliability and, 66

Black start generators, in grid, 62

Blade failures

- in combustion turbines, 36
- in steam generating plant operations, 26–27

- Boiler, in steam generating plant operations, 23–24
- Boiler losses, in steam generating technologies, 22
- Boron, in nuclear reactor control rods, 30–31
- Bottom-up load forecasting, 85
- Breeder reactor, 32
- Brokers, 176, 178
- BTU (British thermal unit), 12, 13t, 14
- Butterfly valves, at Hoover Dam, 39
- C**
- Cadmium, in nuclear reactor control rods, 30–31
- California
 - capacity imbalance penalties in, 169
 - electricity market architecture in, 163
 - energy crisis in, 189, 278–290
 - long-term utility construction in, 125
 - PJM compared with, 288–290
 - wind turbines in, 43
- California Independent System Operator (CAISO), 279–280
 - in California short-term energy market, 281–286
 - PJM compared with, 288–290
 - trading tactics of, 286–288
- California Power Exchange (CALPX), 279–281
 - in California short-term energy market, 281–286
 - PJM compared with, 288–290
 - trading tactics of, 286–288
- California Public Utilities Commission (CPUC), 279–280
- Call options, 175–176, 177
 - in risk management, 248–250
- Capacitor banks, 169
- Capacitors, 56
 - energy consumption of, 54–55
 - power consumption in, 53–54, 55
 - as reactive power providers, 61
- Capacity, for integrated energy suppliers, 276
- Capacity imbalance penalty, 169
- Capacity markets, 161, 173, 178
- Capacity payments, 178, 196–197, 197–199, 201, 202, 210
- Capacity penalty risk, 251
- Capacity price (CP), numerical example of, 196–197
- Capacity price risk, 251
- Capacity pricing, of CCGT and CT tolling agreements, 206–207
- Capacity stack, 139–141
- Capacity tags, 201
- Capacity transactions, in midterm utility planning, 155–156
- Capacity value, energy value and, 210
- Capped index contracts, 213
- Carbon dioxide (CO₂), from coal steam power generation, 28
- Cash flow, 210
 - with retailer's portfolio, 180–181
- Casing cracks, in steam generating plant operations, 26
- CEMS (continuous emissions monitoring system) data set, 186
- Certificates, for capacity markets, 178
- Chain reactions, nuclear power generation and, 30
- Circuit breakers
 - in grid, 60
 - in grid system control, 71
 - in system security, 72
- Circuits, mechanical, 8–9, 10–11
- Cloudiness, as load driver, 16
- Coal, 27
 - energy payment indexed to, 203
- Coal dust, in coal steam power generation, 27
- Coal-fired plant, 258
- Coal steam generation, 21, 22, 27–29
 - costs of, 47
 - environmental damage of, 47
- Cogeneration, 37, 38
- Collateral, in power purchasing agreements, 206
- Colorado River, Hoover Dam and, 40
- Columbia River, hydroelectric power from, 40
- Combined cycle gas turbines (CCGTs), 37–38, 136, 137, 138, 143
 - with AGC, 58
 - as intermediate units, 258–259, 260–261, 263
 - least-cost dispatch for, 109–110

- net present value assessment for, 197–199, 200t
- tolling agreements involving, 206–210
- Combustion turbines (CTs), 34–36, 137
 - CCGTs versus, 109–110
 - with combined cycle gas turbines, 37–38
 - in energy price forecasts, 195–196, 197
 - least-cost dispatch for, 110
 - in long-term utility planning, 125
 - as peaking units, 259, 261–262, 263
 - tolling agreements involving, 206–210
- Commercial load, 14, 16–17
- Competitive bidding, California versus PJM, 289–290
- Competitive retail choice, in market environment, 161–162, 163
- Complete demand forecast, 89
- Computer systems, for wind power generators, 43
- Condenser
 - in steam generating plant operations, 24
 - in steam generating technologies, 22
- Congestion fee settlement, in California short-term energy market, 284–285
- Congestion price, in California short-term energy market, 283–284
- Constraints. *See* Operating constraints
- Construction, in long-term utility planning, 124–125, 192–193
- Consumers, in California energy crisis, 279. *See also* Customer entries
- Contingency planning
 - in grid operations, 72–74
 - grid reliability via, 64, 65
- Contracts. *See also* Financial products; Floating contract; Interruptible contracts; Interutility contracts; Long-term contracts; Subcontracting
 - in retailer's portfolio, 229–232
 - risk-free and risky, 211–212
 - risk minimization in, 251–252
 - structures of, 212–213
- Contractually fixed load, risk minimization with, 234–237
- Control. *See* System control
- Control devices, for grid system control, 70–71
- Control groups
 - in grid monitoring, 75
 - responsibilities of, 75–76
- Control rods
 - in nuclear power generation, 30–31
 - Three Mile Island accident and, 32–33
- Converters
 - in grid, 60
 - grid real power requirements and, 68
- Coolant
 - in steam generating plant operations, 24
 - in steam generating technologies, 22
- Correlation [$\text{Corr}(X, Y)$], 222–225, 228–229, 235, 238–239, 240, 257–263
 - of diversification with multiple units, 267–269
 - forced outages and, 264
 - producer's portfolio and, 254–257
 - in scatter plots, 225–227
- Cost adder, 159
- Cost curves, 104–108, 133–135, 139, 140, 141
- Cost minimization, 89–94. *See also* Least-cost dispatch
 - for electric power delivery, 2–3
- Cost of construction, for power generation technologies, 45, 46, 47
- Costs
 - in adding generation capacity, 136–137, 138
 - in producer's portfolio, 214
- Counterparties, 178
 - in PPAs, 202
- Covariance [$\text{Cov}(X, Y)$], 222–225, 228
 - with fuel and power price uncertainty, 272
 - producer's portfolio and, 253–257
 - retailer's portfolio and, 231
- Critical factors, for load forecasting, 85, 86, 87
- Current generation, 136. *See also* Electric current
- Current limitations, of AC transmission lines, 58
- Customer consumption, risk associated with, 212
- Customer departure, risk of, 214
- Customer reactive demand, grid power requirements and, 69

- Customers
 - in California energy crisis, 278–290
 - classification of, 14–17
- Customer servicing factors, in long-term planning, 128
- Cycles per second, of output voltage, 50–51
- Cycling CCGT units, least-cost dispatch for, 109–110

- D**
- Daily call, 177–178
- Daily indexed call option, 175–176
- Daily indexed put option, 176
- Daily loads, 15–16
- Daily load shapes, 17–18, 19
- Dams, hydroelectric, 38–40
- Day-ahead ancillary services forecasting, in dispatch execution, 83
- Day-ahead dispatch schedule setting
 - with baseload coal units and marginal cost optimization, 103–108
 - in dispatch execution, 83–84
 - with hydroelectric power and peak shaving, 102–103
 - simple model for, 89–94
- Day-ahead electricity demand forecasting
 - in dispatch execution, 83
 - of load and ancillary service requirements, 84–89
- Day-ahead ISO index risk, 251
- Day-ahead market clearing price, 175
- Day-ahead markets, delivery-day schedule adjustments in, 187–189
- Day-ahead planning/scheduling
 - in California short-term energy market, 282–285, 285–286
 - California versus PJM, 288–290
 - dispatch execution and, 81–84
 - for electric power delivery, 2–3, 5
 - grid reliability via, 64, 65
 - in maintaining system stability, 73
 - in short-term market design, 164–166
- Day-ahead schedule adjustments, real-time, 84
- Day-ahead supply forecast, in dispatch execution, 83
- Day-ahead utility-owned generation scheduling, in dispatch execution, 84
- DC transmission lines, in grid, 59
- Death Star trading tactic, in California energy crisis, 287–288
- Debt, transmission upgrades and, 201
- Dec bids, in California short-term energy market, 284
- Decoupled production companies, in market architecture, 163
- Default protection, in power purchasing agreements, 205–206
- Defaults
 - in California energy crisis, 280–281
 - in payments, 214
- Demand bidding
 - asset management and, 180
 - in California short-term energy market, 282
 - by integrated energy company, 189–190
 - in short-term market design, 164
- Demand curve, 244
- Demand forecasting, day-ahead, 83
- Demand for electricity, 14
- Demand function, 244, 245–248, 258
- Deregulation
 - of electric power industry, 1
 - in market architecture, 163
- Detroit Edison, in August 14, 2003 blackout, 78
- Diagnostic testing, in steam generating plant operations, 26–27
- Dice. *See* Fair dice; Fair die
- Direct current (DC), 59
- Disconnecting equipment, in grid system control, 71
- Discounted future values, 210
- Discount rates, 210
- Discrete probability set, 216
- Discrete random variable, 216, 229
- Dispatch. *See also* Least-cost dispatch
 - determining economic, 165–166, 167–168
 - of environmentally constrained resource, 159–160
 - operating parameters for, 82t
 - planning and execution of, 81–84
 - for profit maximization, 95–99
- Dispatch scheduling
 - in California short-term energy market, 283

day-ahead, 83–84
 in midterm utility planning, 152

Distribution lines
 in grid, 60, 63, 64
 grid real power requirements and, 68

Distribution switches, in grid, 62, 63

Diversification, risk minimization via, 265–270

E

Earnings
 producer's portfolio and, 253
 as random variable, 221
 retailer's portfolio and, 229–232

Eastern Interconnect
 in August 14, 2003 blackout, 78–79, 80
 delivery-day adjustments in, 189
 project financing in, 199

Economic dispatch, determining, 165–166, 167–168

Efficiency
 of combined cycle gas turbines, 37–38
 of hydroelectric power generation, 38
 of steam generation technologies, 22–23

Electrical energy, 7

Electrical force, 9

Electrical machinery, reactive and resistive elements in, 56

Electrical utilities, vertically integrated, 1–3

Electric current, 9
 unit of, 11

Electric energy markets, 161

Electric field, in generator, 9–10

Electric generation, 9–12

Electric generator, 9–10
 for wind turbines, 44

Electricity markets, worldwide, 163

Electric potential, unit of, 11

Electric power delivery, infrastructure for, 2, 4

Electric power industry, business structure in, 1

Electromagnet, in generator, 9–10

Electrons, in electric current, 9–10

Emissions, from combustion turbines, 36

Emissions reduction technologies, in coal steam power generation, 28–29

Energy, 7–14
 electrical, 7
 forms of, 7–8
 measurement of, 7–8
 mechanical, 7, 8–9, 10
 thermal, 7
 units of, 12, 13t

Energy component, in price forecasts, 193–194

Energy consumption, 9
 of resistors, 53

Energy-limited resources
 bidding of, 186–187, 187–189
 in midterm market design, 179
 in midterm utility planning, 154–155, 159–160

Energy markets
 day-ahead supply bidding into, 165
 in midterm market design, 173–178

Energy payment, 202
 structuring, 203

Energy price forecast, numerical example of, 195–196, 197t

Energy value, capacity value and, 210

Enrichment, of uranium, 30

Environmental concerns, 47, 48
 with hydroelectric power generation, 40, 48
 in long-term utility planning, 123, 125, 147
 nuclear-fuel-related, 32, 48

Environmentally constrained resources, in midterm utility planning, 155, 159–160

Equipment failure, planning for, 64–66

Europe, electricity market architecture in, 163

Excess fuel burn penalty, 204

Exciter, in steam generating plant operations, 24

Exit fees, long-term market design and, 171

Expected value $[E(X)]$, 217, 218, 219, 220–221

F

Fair coin, outcome set for, 216, 217, 223, 224. *See also* Penny and dime toss; Penny toss

- Fair dice, outcome sets for, 216, 217, 218, 219, 220, 224
- Fair die, outcome set for, 216, 217–218, 223
- Fatboy trading tactic, in California energy crisis, 286–287
- Feasibility, in network least-cost dispatch, 118–120
- Federal agencies, in long-term utility planning, 123, 125
- Federal Energy Regulatory Commission (FERC)
grid reliability and, 65
transmission upgrades and, 173, 201
- Feedback control, AGC as, 57–58
- Financial hedging, 174–178. *See also* Hedging
- Financial products, in midterm market design, 173–174
- Financing. *See also* Cost entries
for adding generation capacity, 138–141
long-term market design and, 171–172, 173
in long-term utility planning, 124, 126
- Fine particles (PM_{2.5}), from coal steam power generation, 28
- First Energy, in August 14, 2003 blackout, 77–78, 80
- Fission, nuclear power generation via, 29, 30
- Fixed costs, in adding generation capacity, 136–137, 138
- Fixed for floating contracts, 175, 251, 256
in risk minimization, 234
- Fixed fuel costs, producer's portfolio with single unit and, 253–255
- Fixed load, risk minimization with, 234–237
- Fixed output, producer's portfolio with single unit and, 253–255
- Fixed payment contracts, 213, 214
- Fixed-quantity contracts, 202
- Fixed volume contracts, risk in, 213
- Floating contract, 174–178. *See also* Fixed for floating contracts
- Foot-pound (ft-lb), 8, 13t
- Forced outage rate, as operating parameter, 82t
- Forced outages
in midterm utility planning, 154–156
in producer's portfolio, 215
in risk assessment, 263–264
- Forecasts, in long-term planning, 128–129.
See also Day-ahead electricity demand forecasting; Load forecasts; Price forecasts; Supply forecasting
- Formulas, for calculating risk, 228–229.
See also Mathematical models; Numerical examples
- 48-hour dispatch plan, 100
- France, nuclear power facilities in, 47, 103
- Free market economy, in California energy crisis, 279
- Frequency, 51, 56
of output voltage, 50–51
- Frequency regulation, by generators, 57
- Frozen coal, in coal steam power generation, 29
- Fuel(s)
for combustion turbines, 34–35, 35–36
disposal of spent nuclear, 32
for nuclear power generation, 30, 31–32
unit conversion and, 12–14
- Fuel costs, energy payment indexed to, 203
- Fuel delivery, in long-term utility planning, 124
- Fuel markets, 161
- Fuel price uncertainty, 271–274
- Fuel start-up amount, as operating parameter, 82t
- Fusion, nuclear power generation via, 29–30
- Future value
for integrated energy suppliers, 274–276
of single generation unit, 252
- G**
- Gas price, energy payment indexed to, 203
- Gearing mechanism, for wind power generators, 44
- Generation capacity
adding, 131–143
adding/retiring within a network, 148–151
adding/retiring within a single control area, 143–147

- adding/retiring with transmission to a single control area, 147–148
 - Generation outages, in midterm utility planning, 153
 - Generation project development, in long-term utility planning, 123
 - Generation retirements, within a single control area, 143–147
 - Generation technologies, 7, 21–48
 - cost of construction of, 45, 46, 47
 - grid and, 49, 50–51
 - heat rate characteristics of, 46
 - “report card” for, 47t
 - Generation units, 2. *See also* Generators
 - future value of, 252
 - Generators, 9–10, 50–51. *See also* Generation units
 - as grid equipment, 57
 - grid real power requirements and, 68, 69
 - in grid system control, 70
 - in producer’s portfolio, 183–184
 - as reactive power providers, 61
 - for wind turbines, 44
 - Geographically limited blackouts, in maintaining system stability, 74
 - Geography
 - as load driver, 16
 - pumped storage systems and, 41–42
 - Geometric interpretation, of load
 - uncertainty with price uncertainty, 240–244
 - Get Shorty trading tactic, in California energy crisis, 287
 - Grand Canyon, Hoover Dam and, 40
 - Greenhouse gases, from coal steam power generation, 28
 - Grid, 2, 49–80. *See also* Networks
 - adding units to, 124
 - alternating current and, 49, 51, 52–53, 54, 55, 56
 - in August 14, 2003 blackout, 76–80
 - configuration of, 67–72
 - contingency requirements of, 64–66, 72–74
 - described, 49
 - equipment in, 56–64
 - load and, 49, 51–56
 - in market architecture, 163
 - operation of, 72–76
 - plant to customer delivery via, 62–64
 - power generation and, 49, 50–51
 - reliability of, 64–66, 162
 - in steam generating plant operations, 24
 - transmission project development for, 126–127
 - Grid assessment, in long-term utility planning, 124
 - Grid management
 - for electric power delivery, 2–3, 5
 - real-time, 120–121
 - Gross domestic product (GDP)
 - as load driver, 14, 15, 17
 - in long-term planning, 129, 130–131
 - Guaranteed operational costs, energy payment indexed to, 203
 - Guarantees, producer ownership with, 172
- H**
- Hazardous emissions, from coal steam power generation, 27–28, 28–29
 - Heat rate characteristics, for power generation technologies, 46
 - Heat rate curve, as operating parameter, 82t
 - Heat recovery steam generator (HRSG), 37, 38
 - Hedging, 251–252, 257–263. *See also* Financial hedging; Optimal hedge
 - geometric interpretation of, 240–244
 - by integrated energy suppliers, 276–277
 - producer’s portfolio and, 253–257
 - profit function with linear demand and, 246–248
 - regression formula for, 248
 - retailer’s portfolio and, 231–232
 - via diversification with multiple units, 265–270
 - Histograms, 220
 - Holidays, peak summertime load and, 88
 - Hoover Dam, 38, 39, 40, 42
 - Hourly demand forecasts, 89
 - Hourly price, determining, 165–166
 - Hourly price and supply requests, in California short-term energy market, 282–283
 - Household items, power requirements of, 15t
 - Households, power requirements of, 14–15
 - Humidity, as load driver, 16

- Hydroelectric power, 38–42
 environmental concerns of, 48
 least-cost dispatch and, 111, 112
 in midterm utility planning, 154
 peak shaving and, 102–103
 reliability of, 47
 system maintenance and performance of, 42
- Hydrogen, Three Mile Island accident and, 33, 34
- I**
- Imbalance penalties, 167–170
 for integrated energy suppliers, 276
 load forecasts to reduce, 182–183
 in power purchasing agreements, 204
- Imbalance penalty risk, 251
- Impact studies, long-term market design and, 171
- Import disruption, as control group responsibility, 76
- Inc bids, in California short-term energy market, 284
- Income, via producer's portfolio, 214
- Incremental heat rate, as operating parameter, 82t
- Incremental load, 140
- Incremental load duration curves, 133–135, 135–141
- Incumbent utilities, in California energy crisis, 278–279
- Independent construction, 192–193
- Independent power producers (IPPs), 4, 5.
See also Power producers
 in California energy crisis, 278–279, 279–280
 defaults by, 206–206
 independent construction projects and, 192–193
 in market architecture, 162–163
 in merchant plant project analysis, 193, 199
 PPAs with, 202, 204
 in tolling agreements, 206–210
 transmission upgrades and, 173
- Independent system operator (ISO), 4, 5.
See also California Independent System Operator (CAISO); ISO entries
 asset management and, 180
 in California energy crisis, 279
 California versus PJM, 289–290
 financial hedging by, 174–178
 independent construction projects and, 193, 201
 integrated energy company portfolio and, 190–191
 maintenance scheduling by, 179
 in market architecture, 163
 ownership of, 171–172
 producer's portfolio and, 184–189
 reliability concerns and, 162
 retailer's portfolio and, 181, 182–183
 in short-term market design, 164–170
 transmission upgrades and, 173, 201
- Indexed call options, 175–176
- Indexed payment contracts, 213
- Indexed put options, 176
- Inductance, of AC transmission lines, 58–59
- Inductors, 56
 energy consumption of, 54–55
 power consumption in, 53–54, 55
 as reactive power providers, 61
- Industrial load, 14, 16–17
- Informational requirements, for midterm utility planning, 152–156
- Infrastructure, for electric power delivery, 2, 4
- Infrastructure additions, 192
- Instability, system, 72–73
- Integrated energy companies, in short-term markets, 189–191
- Integrated energy suppliers, midterm market risk management by, 274–277
- Intermediate unit, 258–259, 260–261
- Internal computer systems, for wind power generators, 43
- Internal motors, for wind power generators, 44
- Interruptible component, in load bid, 181–182
- Interruptible contracts, 182
- Interruptible load, 20–21
- Interutility contracts, in midterm utility planning, 155–156

- Interventions, in maintaining system stability, 73–74
- Intraday markets, 166
 - delivery-day schedule adjustments in, 187–189
- Intraday price risk, 251
 - for integrated energy suppliers, 275–276
- Investment analysis, 192–210
 - long-term, 4
 - transmission upgrades in, 201–202
- ISO day-ahead index, in contracts, 213, 214. *See also* Independent system operator (ISO); Load-weighted day-ahead ISO index (*P*)
- ISO index activated-interruptible service, in contracts, 213, 214

- J**
- Joint probability distribution, 221, 252

- K**
- Kilowatt (KW), 13t
- Kinderdijk, 43

- L**
- Lake Meade, 38, 42
- Lambda. *See* System lambda
- Land costs, in generation additions and retirements, 147
- Least-cost dispatch
 - model for, 89–94
 - in a network, 113–120
 - for profit maximization, 95–99
 - in single control area with operating constraints, 99–111
 - in single node with spinning reserve and regulation, 111–113
- Lightning protection, in grid, 61
- Limited blackouts, in maintaining system stability, 74
- Linear demand, profit function with, 245–248
- Linear equations, for load forecasting, 85, 86
- Linear regression, in load forecasting, 85, 87, 88
- Load, 7, 14–21, 56
 - contractually fixed, 234–237
 - grid and, 49, 51–56
 - for integrated energy suppliers, 275–276
 - interruptible, 20–21
 - in midterm utility planning, 152–153
- Load balancing, real-time, 81
- Load bids, retailer's portfolio and, 181–183
- Load drivers, 14–17
- Load duration curves, incremental, 133–135, 135–141
- Load elements, 52–55
- Load-following capabilities, grid reliability and, 66
- Load forecasts, 2–3, 84–89. *See also* Load predictions
 - in California short-term energy market, 282
 - developing, 85–89
 - imbalance penalties and, 182–183
 - in long-term planning, 129–131, 135–141
 - in short-term market design, 164
- Load management, for electric power delivery, 3, 5–6
- Load predictions, 20. *See also* Load forecasts
- Load requirements, day-ahead demand forecasting of, 84–89
- Load retailers, in market architecture, 162–163
- Load shapes, 17–20, 21. *See also* Power requirements
- Load uncertainty with fixed index, risk minimization with, 237
- Load uncertainty with price uncertainty, risk minimization with, 238–244
- Load-weighted day-ahead ISO index (*P*), 238, 239, 259–263
 - calculating for diversification with multiple units, 267–269
 - calculating for producer's portfolio, 253
 - calculating for retailer's portfolio, 230
 - forced outages and, 263–264
 - with fuel and power price uncertainty, 271–273
 - geometric interpretation of, 240–244
 - for integrated energy suppliers, 274–276
 - options and, 248–250
 - profit function with linear demand and, 245–248
- Local agencies, in long-term utility planning, 123, 125

- Local markets, long-term market design and, 170
- Locational marginal pricing, 169–170
- Long-term contracts, 171
 - PPAs as, 202–210
- Long-term market design, 170–173
- Long-term planning
 - for electric power delivery, 2, 3, 4, 122–151
 - load forecasting for, 129–131, 135–141
 - in market environment, 192–210
 - midterm planning versus, 152, 156
 - reserve requirements in, 151
- Los Angeles Department of Power and Water (LADPW), 279
- M**
- Machinery, reactive and resistive elements in, 56
- Magnetic field, in generator, 9–10
- Magnetic force, 9–10
- Maintenance
 - in coal steam power generation, 29
 - reliability concerns and, 162
 - in steam generating plant operations, 25–27
- Maintenance outages, in midterm utility planning, 153
- Maintenance policies, in producer's portfolio, 215
- Maintenance scheduling, in midterm market design, 179
- Marginal cost curves, 104–108
- Marginal cost of production, 95. *See also* System lambda
 - in price forecasts, 193–194
- Marginal costs, optimization using, 103–108
- Marginal pricing, 169–170
- Market clearing price, 168
 - determining, 169–170
- Market environment, 161–179
 - in California energy crisis, 279–281
 - California versus PJM, 288–290
 - investment setting in, 192–193
 - long-term, 161, 170–173, 192–210
 - midterm, 161, 173–179
 - power delivery chain in, 1, 3–6
 - principles and architecture of, 161–163
 - short-term, 161, 164–170
- Market implementation, California versus PJM, 290
- Market instruments. *See also* Contracts; Options
 - in diversification with multiple units, 266–268
 - with fuel and power price uncertainty, 271–274
 - in midterm market design, 173–178
 - producer's portfolio with, 190–191, 215, 253–257
 - producer's portfolio without, 184–189
 - retailer's portfolio with, 191
 - retailer's portfolio without, 181–183
 - risk minimization via, 232–248
- Market price signals, 172
- Markets, 161
 - for electric power, 1, 3–4
 - system lambda and, 99
- Market substitution rights, in power purchasing agreements, 205
- Mathematical models. *See also* Formulas; Numerical examples
 - for adding generation capacity, 132–143
 - for adding/retiring generation capacity within a network, 148–151
 - for adding/retiring generation capacity within a single control area, 143–147, 147–148
 - for integrated energy suppliers, 274–276
 - for least-cost dispatch, 89–94, 100–111, 112–113
 - for load forecasting, 85–89
 - in long-term planning, 128–129
 - in midterm utility planning, 157–160
 - of network least-cost dispatch, 115–120
 - of producer's portfolio, 183–184
 - of producer's portfolio with market instruments, 190–191
 - for profit maximization, 95–99
 - of retailer's portfolio, 180–181
- Max expression, 96
- Maximum capacity, as operating parameter, 82t
- Maximum capacity penalty, 204

- Measurement
 - of energy, 7–8
 - units of, 9–12
 - Mechanical circuit, 8–9, 10–11
 - Mechanical energy, 7, 8–9, 10
 - unit conversion and, 12, 14
 - Megawatt (MW), 11–12, 13t, 14, 55, 56
 - Megawatt-hour (MWH), 12, 13t, 14
 - Merchant plant, project analysis for, 193–202
 - Mercury, from coal steam power generation, 28
 - Merit order stack, in adding generation capacity, 136, 139–140
 - Meters, real-time monitoring with, 183
 - Midterm market design, 173–179
 - Midterm planning
 - for electric power delivery, 3, 5–6, 152–160
 - risk management in, 211–277
 - Midwest Independent System Operator (MISO), in August 14, 2003 blackout, 77, 80
 - Min expression, 91, 101, 112–113, 116–117, 132, 142, 145, 147, 149, 157
 - Minimum capacity, as operating parameter, 82t
 - Minimum downtime, as operating parameter, 82t
 - Minimum uptime, as operating parameter, 82t
 - MMBTU (million BTUs), 12, 13t, 14
 - Models. *See* Mathematical models
 - Monitoring, in grid operations, 74–75
 - Monitoring systems, in grid, 62
 - Monthly indexed call option, 175
 - Monthly indexed put option, 176
 - Motors, for wind power generators, 44
 - Mountain river/stream systems,
 - hydroelectric power from, 40–41
 - Multiple units, risk minimization via, 265–270
 - MVAR (mega voltage ampere reactance), 55, 56. *See also* Volt-ampere
- N**
- National Electricity Reliability Council (NERC), 186
 - Natural gas, for combustion turbines, 35, 36
 - Negative correlation, 223
 - in scatter plots, 226
 - Netherlands, wind power in, 42–43
 - Net present value (NPV), 179. *See also* Present value (PV)
 - Net present value assessment, 193
 - for CCGT, 197–199, 200t
 - of CCGT and CT tolling agreements, 207–210
 - transmission upgrades in, 201–202
 - Network reactive demand, grid power requirements and, 69
 - Networks. *See also* Grid
 - adding/retiring generation capacity within, 148–151
 - in California energy crisis, 279
 - least-cost dispatch in, 113–120
 - market clearing price in, 169–170
 - reliability concerns in, 162
 - Network schematic, 67
 - Neutrons
 - breeder reactors and, 32
 - nuclear power generation and, 30
 - Nitrogen oxides (NOx), from coal steam power generation, 28
 - Nodal system diagram, 114
 - Nodes, in networks, 114–115
 - Nondelivery, penalties for, 204
 - Normal distribution, in midterm utility planning, 153
 - Nuclear energy, 29
 - Nuclear reactors, 30–31
 - refueling of, 31–32
 - Nuclear steam generation, 29–34
 - environmental concerns of, 48
 - flexibility of, 47
 - Nuclear units, scheduling refueling of, 159
 - Numerical examples. *See also* Formulas; Mathematical models
 - with baseload coal units, 103–108
 - baseload unit, 258, 259
 - of capacity price, 196–197
 - of capacity selection, 137–141
 - of CCGT net present value, 197–199, 200t
 - with CCGTs, 109–110
 - with combustion turbines, 110

- of delivery-day schedule adjustments, 187–189
 - of diversification with multiple units, 266–270
 - of financial hedging with floating contract, 174–178
 - with fuel and power price uncertainty, 271–273
 - of hydroelectric power and peak shaving, 102–103
 - intermediate unit, 258–259, 260–261
 - of least-cost day-ahead dispatch scheduling, 92–94
 - nuclear unit, 103
 - peaking unit, 259, 261–262
 - of present value calculation, 194–195
 - of price forecast, 195–196, 197t
 - with producer's portfolio, 252–257
 - of profit maximization problem, 97–99
 - with retailer's portfolio, 230–232
 - of risk management statistical techniques, 215–229
 - of risk minimization, 233–248
 - of tolling agreements, 206–210
- O**
- Objectives, in long-term planning, 127–128
 - Offline units, in steam generating plant operations, 25
 - Oil extraction, 38
 - On-peak market instruments, 191
 - Operating constraints
 - least-cost dispatch within, 99–111
 - in networks, 113–120
 - Operating parameters, in dispatch execution, 82t
 - Optimal bidding, producer's portfolio and, 185
 - Optimal heat rate, as operating parameter, 82t
 - Optimal hedge, 248
 - geometric interpretation of, 240–244
 - in risk minimization, 233, 236
 - Optimization problem
 - for adding generation capacity, 132–133, 135–141
 - for baseload coal with marginal cost optimization, 103–108
 - day-ahead dispatch scheduling as, 90–94
 - for generation additions/retirements, 143–147, 147–148
 - improved, 141–142
 - in long-term planning, 129
 - for midterm utility planning, 156–160
 - Options, 175–177
 - in risk management, 248–250, 251–252
 - with fuel and power price uncertainty, 271–273
 - Options-type valuations, 210
 - Outages. *See also* Forced outage rate; Forced outages; Transmission outages; US-Canada Power System Outage Task Force
 - as control group responsibility, 75, 76
 - in steam generating plant operations, 25–27
 - system adequacy and, 72
 - Outcomes. *See* Scenario outcomes
 - Outcome sets, in statistics, 216–222
 - Output control, in steam generating plant operations, 25
 - Output control systems, for wind power generators, 45
 - Output-price uncertainty, 257–263
 - Output uncertainty
 - in diversification with multiple units, 266–268
 - producer's portfolio with single unit and, 256–257
 - Output voltage, from generator, 50–51
 - Oxidation, 8
- P**
- Payment defaults, risk of, 214
 - Payments
 - in contracts, 211–212
 - structuring, 202–204
 - Peaking unit, 259, 261–262, 265
 - Peak shaving, hydroelectric power and, 102–103
 - Peak summertime load, forecasting, 86–88
 - Penalties
 - capacity imbalance, 169
 - imbalance, 167–170, 182–183, 204, 276
 - in power purchasing agreements, 204
 - Penny and dime toss, outcome set for, 221–222

- Penny toss, outcome set for, 216, 217, 218–219. *See also* Fair coin
- Penstocks, at Hoover Dam, 39
- Per capita GDP, as load driver, 14, 15, 17
- Permitting, in long-term utility planning, 123, 124, 125
- Phase shifters, in grid system control, 70–71
- Phase transition, water to vapor, 22–23
- Physical instruments, 176–177
- Pipeline construction, in long-term utility planning, 124
- PJM (Pennsylvania, New Jersey, Maryland) California compared with, 288–290
 - competitive/noncompetitive pricing in, 185–186
 - delivery-day adjustments in, 189
 - electricity market architecture in, 161, 163
 - real-time balancing in, 167
- Planned generation, 136
- Planning, 127–129. *See also* Long-term planning; Midterm planning; Short-term planning
 - for electric power delivery, 2–3, 4, 5–6
 - in long-term market design, 170–171
- Plant lifetime, in long-term planning, 128
- Plant operations, in steam generating technologies, 23–25
- Plant to customer delivery, via grid, 62–64
- Plutonium, 32
- Population, as load driver, 14, 15, 17
- Population changes, in long-term planning, 129, 130–131
- Portfolio
 - for integrated energy company, 189–191
 - for integrated energy suppliers, 276–277
 - producer's, 183–184, 184–189, 190–191, 214–215, 252–257
 - retailer's, 180–181, 181–183, 191
- Portfolio development, 122
- Portfolio of units, 92–94, 97–99
- Positive correlation, 222
 - in scatter plots, 225
- Power, 7, 8
 - grid and, 51–56
 - hydroelectric, 38–42
 - reactive, 51–55, 56
 - real, 51–55, 56
 - units of, 11–12, 13t
 - wind, 42–45
- Power component, in price forecasts, 193–194
- Power delivery chain
 - in market environment, 1, 3–6
 - in vertically integrated utilities, 1–3
- Power flow analysis
 - in midterm utility planning, 160
 - in network least-cost dispatch, 118–120
- Power flow problem, in maintaining system stability, 73
- Power flows, system adequacy and, 71
- Power generation, in California energy crisis, 278–279
- Power grid, in steam generating plant operations, 24. *See also* Grid
- Power industry, business structure in, 1
- Power limit, of generators, 57
- Power losses
 - grid real power requirements and, 69
 - in networks, 115
- Power markets, liquidity of, 274
- Power plants
 - long-term market design and, 170
 - operational efficiency of, 203
 - power generated by, 12–14
- Power price
 - energy payment indexed to, 203
 - uncertainty in, 271–274
- Power producer risk, in midterm planning, 214–215
- Power producers. *See also* Independent power producers (IPPs)
 - midterm market risk management by, 252–274
 - in short-term markets, 183–189
- Power purchasing agreements (PPAs), 202–210
 - default protection in, 205–206
 - independent construction projects and, 192–193
 - issues related to, 204
 - market substitution rights in, 205
 - penalties in, 204
 - pricing and valuation in, 206–210
 - structuring, 202–204

- Power requirements, 8–9. *See also* Load shape
 - of household items, 15t
 - of households, 14–15
 - Power stations, grid and, 62, 63
 - Power threshold, in steam generating plant operations, 24–25
 - Power transfer capacity, in networks, 114–115
 - Present value (PV), calculating, 194–195. *See also* Net present value assessment
 - Price adjustment risks, 251
 - Price curves, 194
 - Price-driven interruptible contracts, 182
 - Price forecasts, 210
 - in merchant plant project analysis, 193–194, 201
 - numerical example of, 195–196, 197t
 - Price requests, in California short-term energy market, 282–283
 - Price risk
 - in contracts, 212, 213–214
 - in producer's portfolio, 215
 - Price signals, long-term market design and, 172
 - Price uncertainty, 271–274
 - in diversification with multiple units, 266–268
 - producer's portfolio with single unit and, 256–257
 - Pricing
 - in California short-term energy market, 283–284
 - competitive/noncompetitive, 185–186
 - delivery-day adjustments in, 187–189
 - in power purchasing agreement, 206–210
 - producer's portfolio with market instruments and, 190–191
 - Primary reserves, 167
 - competitive bidding for, 165
 - as control group responsibility, 75
 - grid reliability via, 65–66
 - Private ownership, reliability concerns and, 162
 - Probabilistic approach, in midterm utility planning, 153, 160
 - Probability distribution. *See also* Statistics for hedged/unhedged portfolio earnings, 231–232
 - joint, 221, 252
 - Probability price distributions, 210
 - Procurement costs, in contracts, 212
 - Producer's portfolio, 183–184, 214–215, 252–257
 - with market instruments, 190–191
 - without market instruments, 184–189
 - Producer ownership, long-term market design and, 172
 - Producer risk, retailer risk versus, 273–274
 - Producers
 - in California energy crisis, 278–290
 - integrated energy suppliers versus, 276–277
 - Production companies, in market architecture, 163
 - Production volume, for integrated energy suppliers, 275–276
 - Profit function, 244
 - Profit function with linear demand, risk minimization with, 245–248
 - Profit margin, 244, 245–247
 - Profit maximization
 - in merchant plant project analysis, 193–194
 - model for, 95–99
 - producer's portfolio and, 185
 - Project development, long-term utility planning in, 122–127
 - Project planning, in long-term market design, 170–171
 - Pumped storage systems, for hydroelectric power generation, 41–42
 - Pumping systems, in steam generating plant operations, 24
 - Put options, 176, 177
 - in risk management, 248–250
- Q**
- Quadratic formula, 235
 - Quick-start reserves, grid reliability via, 66
- R**
- Radiation, from nuclear power generation, 29

- Radioactive waste, management of, 32
- Radioactivity, Three Mile Island accident and, 33, 34
- Ramp-down rate, as operating parameter, 82t
- Ramp-up rate, as operating parameter, 82t
- Ramp-up sequence, as operating parameter, 82t
- Random variables, 216, 218, 221, 229, 252–253
 - correlation and, 222
 - with fuel and power price uncertainty, 271–273
 - scatter plots and, 225–229
- Rate increases, in California energy crisis, 280
- Reactive load, of AC transmission lines, 58–59
- Reactive load elements, 52, 53–55, 56
- Reactive power, 51–55, 56
 - delivery of, 169
 - from generators, 57
- Reactive power demand, grid power requirements and, 69–70
- Reactive power providers, in grid, 61, 63, 64
- Reactive power requirements, of grid, 67, 69–70
- Real power, 51–55, 56
 - delivery of, 169
 - from generators, 57
- Real power requirements, of grid, 67, 68–69
- Real-time balancing, 167–170
 - asset management and, 180
- Real-time day-ahead schedule adjustments
 - in California short-term energy market, 285–286
 - in dispatch execution, 84
- Real-time delivery
 - in California short-term energy market, 286
 - in short-term market design, 164, 167–170
- Real-time grid management, 120–121
 - dispatch execution and, 81–84
 - for electric power delivery, 2–3, 5
- Real-time monitoring, 183
- Real-time price, calculating, 167
- Redundancy, to ensure system adequacy, 71
- Refueling
 - of nuclear reactors, 31–32
 - of nuclear units, 159
- Regional coordinators, 76
- Regression formula, for hedging, 248
- Regression methods, in long-term planning, 130–131
- Regulating transformers, in grid, 60, 62–63, 64
- Regulation
 - in California energy crisis, 278–290
 - as control group responsibility, 75
 - least-cost dispatch in single node with, 111–113
- Regulation services
 - competitive bidding for, 165
 - grid reliability and, 66
- Regulatory limitations, in midterm utility planning, 155
- Regulatory price cap, producer's portfolio and, 185
- Related variables, correlation and covariance for, 224–225
- Reliability. *See also* National Electricity Reliability Council (NERC)
 - in capacity markets, 178
 - of electric power delivery, 2–3
 - of grid, 64–66
 - in market environment, 161–162, 163
 - in network least-cost dispatch, 118
- Reliability coordinators, in grid monitoring, 74, 76. *See also* National Electricity Reliability Council (NERC)
- Remote construction, in generation additions and retirements, 147
- Reserve capacity, grid reliability via, 65–66
- Reserve duration curves, 137
- Reserve requirements, in long-term planning, 151
- Reservoir management, for hydroelectric power systems, 40–41
- Residential load, 14–16, 21
- Resistance, of AC transmission lines, 58
- Resistive load elements, 52–53, 54, 56
- Resistors
 - energy consumption of, 53

- power consumption in, 52–53, 54
- Retailer's demand function, 244, 245–248
- Retailer's portfolio, 180–181, 229–232
 - with market instruments, 191
 - without market instruments, 181–183
- Retailer's profit function, 244, 245–247
- Retailer companies
 - financial hedging by, 174–178
 - in market architecture, 163
 - in short-term markets, 164–170, 180–183
- Retailer risk
 - in midterm planning, 211–214
 - producer risk versus, 273–274
- Retailers
 - in California energy crisis, 278–290
 - integrated energy suppliers versus, 276–277
 - midterm market risk management by, 229–252
- Retirements, within a single control area, 143–147
- Ricochet trading tactic, in California energy crisis, 287
- Risk
 - in power plant operational efficiency, 203
 - with producer's portfolio, 252–257
 - with retailer's portfolio, 231–232
- Risk elimination, 238, 256–257
- Risk formulas, 228–229
- Risk management
 - for electric power delivery, 5–6
 - by integrated energy suppliers, 274–277
 - in midterm markets, 211–277
 - statistical techniques in, 215–229
- Risk minimization, 251–252, 253–257
 - with fuel and power price uncertainty, 271–274
 - selecting market instruments for, 232–248
 - via diversification with multiple units, 265–270
- Risk mitigation
 - by integrated energy suppliers, 275–276
 - producer's portfolio and, 253–257
 - retailer's portfolio and, 231–232
- Rotating blackouts, in maintaining system stability, 74
- Rotor, 50
 - in generator, 9, 10
- Run of river system, hydroelectric power from, 40
- S**
- Sammis-Star line, in August 14, 2003 blackout, 78, 79
- SCADA (supervisory control and data acquisition) systems, in grid, 62, 70
- Scatter plots, 225–229
- Scenario outcomes, in midterm utility planning, 153
- Schedule adjustment bidding, in California short-term energy market, 283–284
- Schedule adjustments
 - in California short-term energy market, 283–284
 - delivery-day, 187–189
- Scheduled outages, of AC transmission lines, 59
- Scheduling
 - as control group responsibility, 76
 - reliability concerns and, 162
- Seasonal daily load shapes, 19–20, 21
 - in long-term planning, 130–131
- Seasonal loads, 15–16
- Secondary dispatch rights, 205
- Secondary reserves, 167
 - competitive bidding for, 165
 - as control group responsibility, 75
 - grid reliability and, 66
- Security, of grid, 67, 72
- Selective catalytic reduction (SCR), in coal steam power generation, 28–29
- Service interruptions, in maintaining system stability, 73
- Servomechanical compensators, as reactive power providers, 61
- Settlement price
 - geometric interpretation of, 240–244
 - profit function with linear demand and, 246–248
- Shaping coefficient, in long-term planning, 130–131
- Short-term market design, 164–170
- Short-term markets
 - asset management in, 180–191
 - in California energy crisis, 281–286

- Short-term planning
 - for electric power delivery, 2–3, 5, 81–121
 - midterm planning versus, 152
- Shutdowns, of combustion turbines, 36
- Simple method, in long-term planning, 130, 131
- Single control area
 - adding/retiring generation capacity within, 143–147, 147–148
 - least-cost dispatch in, 99–111
- Single node, least-cost dispatch in, 111–113
- Siting, in long-term utility planning, 123, 126
- Snowfall, mountain river systems and, 41
- Software, in midterm utility planning, 160
- Solution algorithm, for profit maximization problem, 96–99
- Spent fuel, disposal of nuclear, 32
- Spinning reserves
 - grid reliability and, 65
 - least-cost dispatch in single node with, 111–113
 - in maintaining system stability, 73
 - in network least-cost dispatch, 117
- Stability, maintaining system, 72–73
- Standard bidding, 168
- Standard deviation [SD(X)], 218, 219, 220–221, 237, 239
 - correlation and, 222
 - covariance and, 222
 - of diversification with multiple units, 266–269
 - with fuel and power price uncertainty, 273
 - producer's portfolio and, 254–257
 - retailer's portfolio and, 231
 - in risk assessment, 264–265
 - in risk measurement, 215–216
- Standard industry units, 11–12, 13t
- Start-up cost, 168
 - as operating parameter, 82t
- Startups, of combustion turbines, 36
- Start up time, as operating parameter, 82t
- State agencies, in long-term utility planning, 125
- Static synchronous compensators (statcoms), as reactive power providers, 61
- Static VAR compensators, as reactive power providers, 61
- Station buses, in grid, 61–62, 63, 64
- Statistics, for risk management, 215–229
- Stator, 50
 - in generator, 9, 10
- Steam
 - in combined cycle gas turbines, 37, 38
 - Three Mile Island accident and, 33–34
- Steam generation, 21–27
 - coal, 21, 22, 27–29
 - nuclear, 29–34
- Stranded cost, in California energy crisis, 280
- Stress
 - in combustion turbines, 36
 - in wind turbines, 45
- Strike price, 176, 177
- Subatomic particles, nuclear power generation and, 30
- Subcontracting, in long-term utility planning, 124–125
- Sulfur dioxide (SO₂), from coal steam power generation, 28
- Summertime daily load shape, 17–18
- Sum notation, 91, 97, 101, 112–113, 116–117, 132–133, 142, 145–146, 147–148, 149–150, 157–158
- Sunshine, as load driver, 16
- Supplier of last resort, in California energy crisis, 280
- Supply, reliability concerns and, 162
- Supply bidding
 - asset management and, 180
 - day-ahead, 165
 - by integrated energy company, 189–190
 - market clearing price and, 170
- Supply buses, 169
- Supply forecasting, day-ahead, 83
- Supply management, for electric power delivery, 3, 5–6
- Supply offers, in California short-term energy market, 282
- Supply requests, in California short-term energy market, 282–283
- Supply stack, 92–94
- Surge protection devices, in grid, 61

System adequacy, of grid, 67, 71–72
 System control, of grid, 67, 70–71
 System feasibility, in network least-cost dispatch, 118–120
 System impact study, long-term market design and, 171
 System instability, contingency planning for, 72–73
 System lambda, 95
 markets and, 99
 for profit maximization, 95–99
 System security, of grid, 67, 72
 System transmission failures, contingency planning for, 72–73

T

Temperature
 in combustion turbines, 34–35, 35–36, 37–38
 as load driver, 16
 peak summertime load and, 87, 88
 Temporal behavior patterns, as load driver, 14, 15–16, 17
 Termination rights, in power purchasing agreements, 205–206
 Thermal energy, 7
 Three Mile Island accident, 32–34
 Time blocks, 19t
 Time horizon
 for generation additions/retirements, 144, 145–146
 in long-term planning, 128, 130–131
 Time-limited interruptible service, in contracts, 213
 Timeline
 in long-term utility planning, 125
 penalties for not meeting, 204
 Tolling agreements, 202
 ancillary service rights in, 205
 examples of, 206–210
 Top-down load forecasting, 85
 Total power output, of generators, 57
 Toxins, from coal steam power generation, 27–28
 Trading companies, 176, 178
 Trading tactics
 in California energy crisis, 278–279, 286–288
 California versus PJM, 289–290

Transformers
 in grid, 60, 62, 63, 64
 grid real power requirements and, 68–69
 Transmission, adding/retiring generation capacity to a single control area with, 147–148
 Transmission companies (TRANSCOs), 4
 Transmission equipment, 4
 Transmission failures, contingency planning for, 72–73
 Transmission information, availability of, 168
 Transmission line outages, as control group responsibility, 76
 Transmission lines
 in grid, 58–59, 63, 64
 in grid system control, 70
 in networks, 114–115
 Transmission maintenance outages, in midterm utility planning, 153
 Transmission markets, 161
 Transmission network reactive demand, grid power requirements and, 69
 Transmission outages, of AC transmission lines, 59
 Transmission project development, in long-term utility planning, 126–127
 Transmission system, reliability concerns and, 162
 Transmission towers, in grid, 63, 64
 Transmission upgrades
 in investment analysis, 201–202
 long-term market design and, 172–173
 Turbine efficiency, in steam generating technologies, 23
 Turbine malfunctions, in steam generating plant operations, 25–27
 Turbines
 combined cycle gas, 37–38
 combustion, 34–36
 at Hoover Dam, 39
 wind, 43–45

U

U-235, for nuclear power generation, 30
 U-238, nuclear power generation and, 30
 U-239, breeder reactors and, 32

- Uncertain output, producer's portfolio with single unit and, 255–256
- Uncertainty, 218, 251. *See also* Load uncertainty with fixed index; Load uncertainty with price uncertainty; Risk entries
- in contracts, 211–212, 213–214
 - in diversification with multiple units, 265–270
 - hedging versus, 232
- Unhedged retailer's portfolio, geometric interpretation of, 240–244
- Uninterruptible component, in load bid, 181–182
- United States. *See also* Federal entries; National Electricity Reliability Council (NERC); US-Canada Power System Outage Task Force
- coal steam power generation in, 27
 - contemporary PPAs in, 202
 - electricity market architecture in, 163
 - grid contingency requirements in, 64–65
 - nuclear units in, 103
 - reliability coordinators in, 74
- Units. *See* Baseload unit; Generation units; Nuclear units; Offline units
- Units of measurement, 9–12
- conversion of, 12–14
 - standard industry, 11–12, 13t
- Units portfolio, 92–94, 97–99
- California versus PJM, 290
- Unit trips, contingency planning for, 72–73
- Unrelated variables
- correlation and covariance for, 223
 - in scatter plots, 226, 227
- Upgrading equipment, long-term market design and, 170
- Upgrading transmission, long-term market design and, 172–173
- Uranium, for nuclear power generation, 30, 32
- US-Canada Power System Outage Task Force
- on August 14, 2003 blackout, 80
- Utilities
- in California energy crisis, 278–290
 - vertically integrated, 1–3
- Utility construction, 192, 193
- Utility environments, investment setting in, 192–193
- Utility-owner generation scheduling, day-ahead, 84
- ## V
- Valuation. *See also* Pricing of CCGT and CT tolling agreements, 207–210
- options-type, 210
- Value-driven interruptible contracts, 182
- Variable costs, for generation additions/retirements, 136–137, 146–147
- Variance [$\text{Var}(X)$], 218, 219, 221, 228
- in diversification with multiple units, 266–269
 - with fuel and power price uncertainty, 272
 - minimizing, 265
 - producer's portfolio and, 253–257
 - retailer's portfolio and, 231
 - in risk minimization, 232–240
- Vertically integrated utilities, power delivery chain in, 1–3
- Volt, 11
- Voltage, 51. *See also* Output voltage
- AC transmission lines and, 59
 - in grid system control, 70–71
- Voltage collapse, of AC transmission lines, 58–59
- Voltage maintenance, by generators, 57
- Volt-ampere, 11–12. *See also* MVAR (mega-voltage ampere reactance)
- Volume, for integrated energy suppliers, 275–276
- Volumetric demand risk, 251
- Volumetric risk
- in contracts, 212, 213, 214
 - in producer's portfolio, 215
 - in retailer's portfolio, 231
- Volumetric uncertainty, contracts with, 213–214
- VOM (variable operations and maintenance) cost
- in midterm utility planning, 159
 - as operating parameter, 82t

W**Water**

- in hydroelectric power generation, 38–40
- in nuclear power generation technologies, 31
- in pumped storage systems, 41–42
- in steam generating technologies, 21–22, 22–23
- Three Mile Island accident and, 33–34

Watt, 13t**Watt-hour, 13t****Weapons-grade uranium, 30****Weather**

- hydroelectric power generation and, 40, 42
- as load driver, 14, 16, 17, 21
- mountain river systems and, 41

Weather-constrained resources, in midterm utility planning, 154–155**Weekends, peak summertime load and, 88****Weekly loads, 15–16****Weekly load shapes, 18–19****Wet scrubbers, in coal steam power generation, 29****Wicket gates, at Hoover Dam, 39****Wind, as load driver, 16****Windmills, 42–43****Wind power, 42–45**

- environmental concerns of, 48
- least-cost dispatch and, 111
- in midterm utility planning, 154
- reliability of, 47

Wind turbines, 43–45**Wintertime daily load shape, 18****Y****Yaw motor, for wind power generators, 44****Yucca Mountain, 32****Z****Zero correlation, 223, 235**

- in scatter plots, 226, 227

Zoning agencies, in long-term utility planning, 123

