ACO. See Ant colony optimization (ACO)
ACS. See Ant colony system (ACS)
ACSA. See Ant colony search algorithms
(ACSA)
Active power generations, 487, 489–490, 493
Actual objective function, 118
Adaptive Hopfield neural network
(AHNN), 349
Adaptive landscapes, 5
Adaptive particle swarm optimization
(APSO), 79–81, 83
Adaptive systems, 43
Adjustment strategy
position within boundary, 347
AHNN. See Adaptive Hopfield neural
network (AHNN)
Algorithms
economic performance, 534
Alpine function, 555
Annealing, 123
Ant colony optimization (ACO), 71
Ant colony search algorithms (ACSA),
89–99, 385
ant behavior, 90
ant colony system, 95
ant system, 94
characteristics, 98
constructive heuristic information, 98
distributed computation, 98
flow, 383
greedy search, 98
IEEE 136-Bus System, 399
implementation, 391
max-min ant system, 95–97
performance, 392, 393, 395
positive feedback, 98
structure, 93
thermal units short-generation
scheduling, 382
Ant colony system (ACS), 92, 95
based algorithm applied to CLF problem,
389
IEEE 136-Bus System, 398
parameters, 392
Ants behavior, 90
Ant system (AS), 92, 94
Applied fuzzy compromise programming
power system controls, 453
proposed interactive DWCP method, 511
Applied interactive procedure, 457, 515
Applied power flow control model
formulated MO optimization model,
509–511
power system controls, 453
Approximate time per run, 366
Approximation functions
power systems applications, 242
APSO. See Adaptive particle swarm
optimization (APSO)
ARMA. See Autoregressive moving
average (ARMA) model
Arrow points
uniform crossover, 37
Artificial initial population
generation expansion, 289–290
Artificial Intelligence Through Simulated
Evolution, 43
AS. See Ant system (AS)
Aspiration plus technique, 114

Modern Heuristic Optimization Techniques. Edited by K. Y. Lee and M. A. El-Sharkawi
Copyright © 2008 by the Institute of Electronics Engineers, Inc.
Asymptotic convergence proof, 26
Attainment function method
- pareto multiobjective optimization, 204
Attainment surfaces, 204
Attractive area
- solution space, 78
Attractive regions, 105
Autoassociator, 269
Autoencoder, 269
Automatic voltage regulator (AVR), 405
Autoregressive moving average (ARMA) model, 240
Average cost over, 366
AVR. See Automatic voltage regulator (AVR)
Azores Islands, 531

Basic operators, 33–37
- control parameters estimation, 38
  crossover, 36–37
- elitist selection, 34
  exponential ranking selection, 34
  linear ranking selection, 34
  mutation, 38
  proportional selection, 35
  selection, 33–35
  tournament selection, 34
  truncation selection, 34
Bayesian update, 19
Benchmark problems
- partition results, 231
Benders decomposition, 301
- approach, 305
  reactive power planning problem, 321–322
Best neighbors, 118
Binary encoding, 38
- shortcoming, 29
Biobjective minimization problem
- fitness computation for NSGA, 200
  VEGA approach, 198
Biobjective optimization
- distance and energy, 190
  Pareto front, 192
Boid, 71, 72, 73
Boiler-turbine model
- power system controls, 419
Border point, 279
Border tracking, 274
Boundary tracking, 272
Brazilian North-Northeastern network, 306
Brazilian North-Northeastern system, 301
Brazilian Southern System, 301
Building block theory, 66
Bus system (6), 137
- comparison of generation costs, 384
  with generation rescheduling, 304, 305
  initial configuration, 303
  optimal solution, 304
Bus system (14). See IEEE 14 bus system
Bus system (30). See IEEE 30 bus system
Bus system (112)
- PSO, 414
  RTS, 412
Bus system (136). See IEEE 136 bus system
Bus system (1217)
- power system controls, 415
Bus voltage, 487, 489–490, 493
EPSO, 559

Candidate list strategies
- TS algorithm, 114
Candidate plants
- technical and economic data, 294
Candidate vector, 179
Capacitor placement similarity with unit commitment problem
- hybrid systems, 539
Capacitors
- fixed, 527
  sizing and location, 527–537
  switched, 527
Cardinality
- MOO, 203
CARE model in Crete, Greece, 542–545
- chromosome compression technique, 544
  chromosome repair, 545
  crossover, 545
  dispatch with fuzzy wind model, 545–546
dynamic mutation rate, 544
- fitness evaluation ramping rules, 547
Lamarckist adaptation, 545
- selection and deterministic crowding, 544
Cascading outage, 262
CCT. See Critical clearing time (CCT)
CFA. See Constriction factor approach (CFA)
Characterization (Trust-Tech) method transformation under stability-retained equilibrium, 210
Child vector creation procedure with DE1 vector representation, 179
with DE2 vector representation, 180
Chromosome compression technique, 544
GA terms, 474
repair, 545
Circuit power flow controller, 494
Class program Deep Blue, 11
Cleverer chromosomes, 538–547
hybrid systems, 540
CLF. See Constrained load flow (CLF) problem
Coding and representation
TS, 104
Coding problem representation
network expansion transmission, 302–303
Coding scheme
block controlled by switching, 542
Coding strategies, 549
Cogeneration coefficients, 373
plant, 373
problem objective, 372
Cogeneration scheduling, 366–379
case study, 373
data, 379
IGA implementation, 370–372
nomenclature, 379
parameters, 379
problem, 367–379
thermal and electric variables, 379
Cogeneration system parameters, 373
Combinatorial optimization algorithms, 96
Common population-based MO algorithms pareto multiobjective optimization, 200–201
Completely stable, 219, 220
Compromise programming
power system controls, 447
Computational intelligent techniques, 261
Computing features, 68
Consequence matrix, 437
Constant cooling rate, 130
Constrained load flow (CLF) problem, 385–399
ASCA, 387–389
construction graph, 387
heuristic ant colony search algorithm implementation, 386–398
problem formulation, 386
test examples, 390
Constrained variables limits and discretization of actions, 391
Constraints crew, 355, 357, 359
handling, 31
GA implementation to ED, 341
PSO implementation to ED, 346–347
maintenance scheduling, 355
multiobjective optimization techniques, 504
power system controls, 447
rejection, 245
repair, 245
resource, 357, 359
Constriction factor approach (CFA)
PSO techniques, 77
Constructive neighborhood, 119
Continuation power flow (CPFLOW) calculation, 414
technique, 405
Control input optimization
power system controls, 431–434
Controller implementation
power system controls, 442–443
Control parameters
FACTS devices, 460, 510, 518
Control setting of capacitor banks, 329
Control targets
FACTS devices, 510
Control variables
formulated MO optimization model, 508
power system controls, 450–452
Convergence in probability, 26
Convergence rate, 33
Cooling rate determination
simulated annealing, 130
Cooling schedule, 126
simulated annealing, 127–130
Cost coefficient, 350
Cost coefficient of test system, 351
Cost minimization
proposed interactive displaced worst compromise programming method, 512
Cost parameters
generating units, 491
Coupled proportional integral controller structure, 421
gains training schedule, 421
CPFLOW. See Continuation power flow (CPFLOW)
Create fuzzy sets window, 154
Creation of offspring
GA terms, 476
Creation procedure in DE (mutation and recombination)
pseudocode, 178
Crew constraints, 355, 357
cost multiplier, 359
Critical clearing time (CCT), 276
Crossover
CARE model in Crete, Greece, 547
differential evolution, 183
exploration capability, 37
GA basic operators, 36–37
mating pool, 371
methods, 291
operation, 419
operator, 441
probability, 478
process, 161
technique pseudocode, 342, 343
Current developments, 12–18
historical theory, 12
no free lunch theorem, 12–13
representations computational equivalence, 14–15
schema theorem in presence of random variation, 16
two-armed bandits and optimal trial allocation, 17–18
Current schedule, 363

DAE. See Differential and algebraic equation (DAE) solver
Darwinian evolution, 3
Darwinistic process, 82, 525
Data and control parameters, 535
DC. See Deterministic crowding (DC)
DDP. See Dynamic decomposition point (DDP) computing
DE. See Differential evolution (DE)
Decision-makers (DM), 502
objectives, 460, 461, 462, 518–520
Decomposition, 117
minimization problem, 230
point, 215, 220, 230
Defects, 124
Defuzzification method, 438
Defuzzification process, 148, 149
Demand-side management (DSM) options, 447
Dependence
fitness function, 31
Determination
simulated annealing, 129
Deterministic crowding (DC)
approach, 544
CARE model in Crete, Greece, 544
GA pseudocode, 344
Diagonals characterization, 109
Didactic strategy, 48
Differential and algebraic equation (DAE) solver, 232
Differential evolution (DE), 171–185
algorithms, 172–174
crossover, 183
defined, 171
encoding, 181
function optimization formulation, 176
fundamentals, 177–180
initial population, 178
key operators, 181–183
mutation, 181–182
mutation creating new vectors, 178–179
optimization example, 184
pseudocode, 180
recombination creating new vectors, 178–179
scheme “1,” 179
selection, 180
virtual population-based acceleration techniques, 174
Direct method, 263
Discrete optimization problems, 238
Displaced worst compromise programming (DWCP), 404, 445
Distance-to-optimum vector, 50
Distributed computation
ant colony search algorithms, 98
Distribution network expansion, 311–317
dynamic planning, 312–315
FRIENDS, 317–329
GA application, 316
Distribution networks prioritizing investments
distribution system applications, 247
Distribution system applications, 244–246
distribution networks prioritizing investments, 247
network reconfiguration for loss reduction, 245
optimal protection and switching devices placement, 246
power systems applications, 244–246
Distribution system in IEEE PES transactions, 313
Diversification, 73, 102
implementation, 118
Diversification process, 103
Diversity, 46
evolution strategies, 58
fitness assignment mechanism, 199
mechanisms, 196
DM. See Decision-makers (DM)
Dominance ranking
pareto multiobjective optimization, 204
Downtime of units, 381
DP. See Dynamic programming (DP)
Drum pressure
power and pressure ramp test, 442
power and pressure step change, 443
DSM. See Demand-side management (DSM) options
DWCP. See Displaced worst compromise programming (DWCP)
Dynamic decomposition point (DDP) computing
local optimal solution computing, 222
Dynamic environments, 9
Dynamic expansion planning, 135
Dynamic load modeling
power systems applications, 239
Dynamic mutation rate
CARE model in Crete, Greece, 544
Dynamic planning
distribution network expansion, 312–315
Dynamic programming (DP), 287
Dynamic space reduction strategy
PSO implementation to ED, 348
schematic, 348
EA. See Evolutionary algorithms (EA)
EC. See Evolutionary computation (EC)
Economic dispatch (ED)
power system scheduling, 337–354
problems, 337
Economic load dispatch (ELD), 471
Economic operation (EO)
membership, 454, 512
Economic performance algorithms, 534
E-constraint
pareto multiobjective optimization, 195
ED. See Economic dispatch (ED)
Edit fuzzy sets window, 155
Edit rules window, 156
EGEAS. See Electric generation expansion analysis system (EGEAS)
ELD. See Economic load dispatch (ELD)
Electrical power
light load level case, 376, 378
power and pressure ramp test, 443
power and pressure step change, 444
Electric generation expansion analysis system (EGEAS), 287
Electricity buying-selling prices, 373
Elitism, 48, 196
MOO, 199
SPEA, 201
Elitist selection
GA basic operators, 34
EM. See Energy margin (EM)
Embedded encoding, 340
Empirical attainment surfaces, 204
Encoding, 26
differential evolution, 181
GA, 28–29, 417
GA implementation to ED, 340
schemes, 340
Energy margin (EM), 276
Enhanced particle swarm optimization method
power system vulnerability assessment, 274
Enhancing mutation process features, 63–64
Environment
fitness function, 44
EO. See Economic operation (EO)
EP. See Evolutionary programming (EP)
Epistasis, 29
EPSO. See Evolutionary particle swarm optimization (EPSO)
Equilibrium manifolds, 220
Equilibrium point, 212
Error back-propagation, 441
ES. See Evolution strategies (ES)
EVALUATION, 81
Evaluation
EPSO, 551
searching points, 81
EvoC, 68
Evolutionary algorithms (EA), 171, 550
advantage, 11
flowchart, 4
genetic structure, 197
library, 68
stochastic convergence, 329
virtual population-based acceleration techniques, 174
Evolutionary computation (EC), 3–20, 237. See also Evolutionary algorithms (EA)
broad applicability, 6
described, 3
method, 272–273
outperform classic methods on real problems, 7
parallelism, 8
power system vulnerability assessment, 272–273
problem-solving with no known solutions, 11
robust to dynamic changes, 9
self-optimization, 10
techniques, 43
using and hybridizing knowledge, 8
Evolutionary particle swarm optimization (EPSO), 81, 83
bus voltage, 559
evaluation, 551
in loss reduction and voltage/VAR control, 556
merits, 553
mutuation, 551
particle reproduction, 552
performance, 556
vs. PSO, 554–556
replication, 551
reproduction, 551
selection, 551
test function, 554–555
Evolutionary programming (EP), 43, 60–63, 404
application in intelligent predictive control, 427–444
bridge to ES, 60
control input optimization, 431–434
controller implementation, 442–443
features, 63–68
flow diagram, 432
intelligent predictive controller structure, 428–429
optimizer, 427–444
power plant model, 430
power system controls, 427–444
reactive power planning at distribution level, 327–329
rule generation and tuning, 438–441
scheme, 61–62
self-organized neuro-fuzzy identifier, 435–437
variants, 63
Evolution strategies (ES), 12, 43–59, 337
diversity, 58
eyearly ES and 1/5 rule, 51–53
extension, 57
features, 63–68
general schemes, 47–49
implementation, 355–364
learning parameter value selection, 56
maintenance scheduling, 355–364
optimum, 53
self-adaptation, 54, 58
Existing plants
technical and economic data, 293
Exit point computing
  local optimal solution computing, 222
Expansion planning, 26
Expectation, 50
Exponential ranking selection
  GA basic operators, 34

FACTS. See Flexible alternating current
  transmission systems (FACTS) devices
Feasible regions, 220
Feasible to unfeasible transition, 107
Features, 265
FGA. See Floating point genetic algorithm
  (FGA)
Financial transmission rights (FTR), 445, 501
Fine-grained GAs, 40
Finiteness and separating property, 212
Fisher’s linear discriminant
  power system vulnerability assessment, 266–267
Fitness
  assignment, 196
  assignment mechanism diversity, 199
  biobjective minimization problem, 200
  computation for NSGA, 200
  computation MOGA, 199
  GA terms, 475
  landscape, 51
  value, 30, 534
Fitness evaluation
  GA, 418
  ramping rules, 547
Fitness function, 30–32, 245
  defined, 475
  dependence, 31
  environment, 44
  evolution, 550
  features, 67
  GA implementation to ED, 344
  generation expansion, 288
  premature convergence, 32
  slow finishing, 32
Fixed capacitors, 527
Fixed length blocks
  coding, 541
Flexible, reliable and intelligent energy
  delivery system (FRIENDS)
  distribution network expansion, 317–329
Flexible alternating current transmission
  systems (FACTS) devices, 243, 404, 445, 471, 492–497
  control, 507–510
  parameters, 460, 510, 518
  targets, 510
  variables, 452
formulated MO optimization model,
  507–510
  numerical results, 497
  optimal scenario, 463, 522
  phase shifter, 492–494
  power injection model, 509
  problem formulation, 496
  series compensator, 495
  with and without, 459, 519
Flipping bits at random, 38
Floating point genetic algorithm (FGA), 475
  convergence nature, 492
  IEEE 14-Bus System, 481, 482
  IEEE-30 bus system, 492
  tuned parameters, 486
Forecasted peak demand, 292
Formulated MO optimization model,
  506–510
  applied power flow control model,
  509–510
  control variables, 508
  FACTS control, 507–510
  power flow control model of FACTS
    devices, 508–510
  power system controls, 449–450
Frequency-based memory
  TS, 116
FRIENDS. See Flexible, reliable and
  intelligent energy delivery system
  (FRIENDS)
FTR. See Financial transmission rights
  (FTR)
Fuel cost parameters, 486
Fuzzification process, 148, 149
Fuzzy control, 154–155
Fuzzy futures, 314
Fuzzy genetic algorithm, 152
Fuzzy inference process, 149
Fuzzy knowledge-based system, 358
Fuzzy particle swarm algorithms, 152
Fuzzy quantifiers
concept, 448
Fuzzy sets, 538–547
theory, 148, 448, 505
Fuzzy systems, 147–167
actions, 148
algorithm presentation, 162
evaluation function, 160
evolutionary algorithms and fuzzy logic, 152
first simulations, 156
fused systems, 151
fuzzy control, 154–155
genetic operators, 161
genetic representation of solutions, 160
genetic training modulus description, 158
hybrid systems integration types, 150–151
illustrative example, 153–162
integration with evolutionary techniques, 150–151
motivation and definitions, 147–149
option defining starting positions, 158
option genetic training, 158–162
parking conditions, 153
problem presentation, 156–157
renovation and selection criteria, 161
scheme, 148
stand-alone systems, 150
stop criteria, 162
tests, 163
weak integration systems, 150
Fuzzy terms, 148
Fuzzy values, 148
Fuzzy wind model
CARE model in Crete, Greece, 545–546

Garver’s system
6-bus, 301
initial configuration, 305
optimal solution, 305
Gaussian mutations, 11
Gaussian random variable, 10
GBA. See Genetic based algorithm (GBA)
GBAGS. See Genetic based algorithm with gradient search (GBAGS)
GBD. See Generalized Benders decomposition (GBD) method
Gbest, 363
model, 73, 348
particle, 361
schedule, 365
Gene
GA terms, 474
Generalized assignment problem (GAP), 120
Generalized Benders decomposition (GBD) method, 322, 405
Generating units
cost parameters, 491
valve point effects in cost function, 491
valve point loading, 491
Generation
cost parameters, 486
IEEE 14-Bus System, 479, 481
initial searching points, 81
network management, 557
and power losses, 498
scheduling, 238
unit system costs, 384
Generational distance
MOO, 203
Generation expansion planning (GEP), 285–296
artificial initial population, 289–290
fitness function, 288
IGA, 293–294
least-cost, 288
numerical examples, 292
numerical results, 295
stochastic crossover, elitism, and mutation, 291
Generator
downtime and maintenance cost, 357
piecewise quadratic cost function, 339
ratings, 356
Genetic, 45
defined, 44
Genetic adjustment
  membership function, 167
Genetic algorithm optimization toolbox (GAOT)
  MATLAB, 476
Genetic algorithms (GA), 25–42, 337
  application, 25, 316
  control system design, 420–424
  convergence rate, 33
  crossover operation, 419
  design results, 423–425
  distribution network expansion, 316
  encoding, 28–29, 417
  fitness evaluation, 418
  fitness function, 30–32
  genetic algorithms, 27
  genetic operations, 419
  IEEE 14-Bus System, 480, 482
  IEEE-30 bus system, 488
  implementation
    flowchart, 362
    maintenance scheduling, 355–364
  implementation to ED, 339–345
    constraints handling, 341
    encoding method, 340
    fitness function, 344
    genetic operations, 342–343
    multistage method and directional crossover, 345
      with smooth cost function, 348
    initialization of population, 418
    iteration execution, 28
    load flow study, 480, 482
    LQR controller designs, 420
    LQR controller results, 425–426
    LQR drum level response, 427
    LQR power response, 426
    LQR pressure response, 426
    mating pool, 419
    method, 418
  modern heuristic search techniques, 25–26
  multiobjective optimization techniques, 505
  mutation operation, 419
  network expansion transmission, 307–308
  OPF, 488
    PI controller, 420, 423–424
    PI drum level response, 425
    PI pressure response, 424, 425
    power system controls, 420–426, 448
    program flow chart, 173
    reproduction operation, 419
    research, 25
    selection process, 418
    solving optimal power flow problems, 471–498
      application examples, 485–488
      chromosome, 474
      creation of offspring, 476
      crossover probability, 478
      FACTS model, 492–497
      fitness, 475
      GA terms, 473–478
      gene, 474
      heuristic crossover, 476
      initialization, 475
      load flow problem, 478
      mutation probability, 478
      nonuniform mutation, 477
      normalized geometric selection, 477
      numerical results, 497
      OPF for loss minimization, 488
      OPF problem, 483–488
      OPF under contingent condition with line capacity limit, 488
      OPF with FACTS devices, 488–497
        phase shifter, 492–494
        population size, 474
        problem formulation, 496
        search space, 473
        series compensator, 495
        stopping rule, 478
    Genetic based algorithm (GBA), 528
      best run, 535
    Genetic based algorithm with gradient search (GBAGS), 528
      best run, 535
      flowchart, 531
    Genetic operations
      GA, 419
        GA implementation to ED, 342–343
    Genetic operators
      characteristics, 247
Genetic training
best results, 158
fuzzy systems, 158–162
iterations, 166
starting positions, 158
Genetic training modulus description
fuzzy systems, 158
Genotype
defined, 44
GEP. See Generation expansion planning (GEP)
Global behaviors
nonlinear dynamical systems, 219
Global best, 201
Global combinatorial optimization, 266
Goal programming
multiobjective optimization techniques, 504
pareto multiobjective optimization, 195
power system controls, 447
Goldberg’s simple GA, 348
Gradient method
power system vulnerability assessment, 272
GRASP. See Greedy randomized adaptive search procedure (GRASP)
Greedy randomized adaptive search procedure (GRASP), 302
Greedy search and constructive heuristic information
ant colony search algorithms, 98
Greek national utility, 525
GroupBest, 274
Guiding solutions, 119
Hamming cliffs, 29
Handling constraints
features, 67
HBDP. See Hybrid dynamic programming (HBDP)
Heuristic ant colony search algorithm
implementation, 386–398
CLF problem ASCA, 387–389
construction graph, 387
problem formulation, 386
test examples, 390
Heuristic crossover
GA terms, 476
Heuristic search techniques
genetic algorithms, 25–26
Hidden failure, 262
Holland, John, 43
HPSO. See Hybrid particle swarm optimization (HPSO)
Hybrid approach justification
voltage/VAR control and loss reduction, 550
Hybrid division/clustering algorithm, 143
Hybrid dynamic programming (HBDP), 385
Hybrid methods
trust-tech paradigm, 225
Hybrid particle swarm optimization (HPSO)
flowchart, 79
searching process, 80
techniques, 78
Hybrid systems, 525–558
biological touch, 541
building a Lamarckian acquisition of improvements, 529–530
capacitor placement similarity with unit commitment problem, 539
capacitor sizing and location and analytical sensitivities, 527–537
cleverer chromosomes need, 540
from Darwin to Lamarck, 528
didactic example analysis, 531–537
illustrative results, 547–549
integration types, 150–151
 evolutional algorithms and fuzzy logic, 152
fused systems, 151
stand-alone systems, 150
weak integration systems, 150
models, 528
reliability, 547
unit commitment, fuzzy sets, and cleverer chromosomes, 538–546
unit commitment problems deceptive characteristics, 538
voltage/VAR control and loss reduction, 550–558
Hybrid Trust-Tech method
structure, 226
Hybrid TS/GA/SA algorithm
network expansion transmission, 310
Hydrothermal coordination, 26
Hypervolume indicator
MOO, 203
IEEE 14 bus system, 394, 396
FGA, 481, 482
GA-based load flow study, 480, 482
generation, loads, and nodal voltages,
modified, 479, 481
operating conditions, 410
optimal control, 411
parameter sensitivity analysis, 412
power system controls, 409–411
P-V curve, 413
RTS, 412
IEEE 30 bus system
cost minimization, 485
FGA convergence nature, 492
GA-based OPF, 488
modified, 496
reactive power planning at generation-
transmission level, 324–325
IEEE 136 bus system
ACSA, 399
ACS and Q-learning algorithms, 398
reactive power control problems, 398
IEEE Proceedings, 237
IEEE Transactions, 237
IGA. See Improved genetic algorithm (IGA)
Implicit parallelism, 15
Improved genetic algorithm (IGA),
292–294, 367, 374
cogeneration scheduling, 370–372
convergence characteristics, 295
generation expansion, 295–297
implementation, 295, 370–372
parameters, 295
Individual learning and cultural
transmission, 71, 72
Inertia weights approach (IWA), 73, 411
Inference process, 149
Initialization
GA population, 418
GA terms, 475
Initial population of strings, 370
Initial training positions, 164
Initiating solutions, 119
Input space
midpoint and proximity, 276
Intelligent methods
pareto multiobjective optimization,
196–202
Intelligent predictive control
power unit, 429
Intelligent predictive controller structure
power system controls, 428–429
Intensification, 73, 102, 117
Intensification process, 103
Interactive compromise programming-
based MO approach to FACTS control,
444–449, 501–519
applied fuzzy compromise programming,
453
applies power flow control model, 453
compromise programming, 447
constraint method, 447
control variables, 450–452
formulated MO optimization model,
449–450
fuzzy set theory application, 448
genetic algorithm, 448
goal programming, 447
implementation, 457, 516
interactive procedure, 449
local power flow control, 454
MO optimization techniques, 446–449
multiobjective optimization techniques,
503–506
numerical results, 457, 516
operation cost minimization, 454
phase 1 model formulation, 456
phase 2 noninferior solution calculation,
456
phase 3 scenario evaluation, 456
power flow control model of FACTS
devices, 450–453
power system controls, 444–449
proposed interactive DWCP method,
453–454
weighting method, 447
with worst compromise displacement,
455–456
Interactive DWCP method
power system controls, 453–454
Interactive procedure
flowchart, 458, 515
multiobjective optimization techniques,
506
<table>
<thead>
<tr>
<th>Term</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactive procedure (Continued)</td>
<td>455–456</td>
</tr>
<tr>
<td>and worst compromise displacement</td>
<td></td>
</tr>
<tr>
<td>Interface branches</td>
<td></td>
</tr>
<tr>
<td>thermal burden, 460, 517</td>
<td></td>
</tr>
<tr>
<td>Intermediary recombination, 66</td>
<td></td>
</tr>
<tr>
<td>Interstitial defect, 124</td>
<td></td>
</tr>
<tr>
<td>Intrinsic parallelism, 15</td>
<td></td>
</tr>
<tr>
<td>Inverted adaptive topography, 5</td>
<td></td>
</tr>
<tr>
<td>Investment, 314</td>
<td></td>
</tr>
<tr>
<td>Iterative Gauss-Siedel method, 174</td>
<td></td>
</tr>
<tr>
<td>IWA. See Inertia weights approach (IWA)</td>
<td></td>
</tr>
<tr>
<td>Jacobian matrix, 327</td>
<td></td>
</tr>
<tr>
<td>JOULETHERMIE research program, 542</td>
<td></td>
</tr>
<tr>
<td>Karhuren–Loève expansion, 266</td>
<td></td>
</tr>
<tr>
<td>Kirchhoff’s current law (KCL), 298</td>
<td></td>
</tr>
<tr>
<td>Kirchhoff’s second law, 299</td>
<td></td>
</tr>
<tr>
<td>Kirchhoff’s voltage law (KVL), 298</td>
<td></td>
</tr>
<tr>
<td>Lagrangian function, 211, 342</td>
<td></td>
</tr>
<tr>
<td>Lagrangian methods, 238, 342</td>
<td></td>
</tr>
<tr>
<td>Lamarckian acquisition of improvements</td>
<td></td>
</tr>
<tr>
<td>hybrid systems, 529–530</td>
<td></td>
</tr>
<tr>
<td>Lamarckism, 525, 560</td>
<td></td>
</tr>
<tr>
<td>defined, 526</td>
<td></td>
</tr>
<tr>
<td>Lamarckist adaptation</td>
<td></td>
</tr>
<tr>
<td>CARE model in Crete, Greece, 545</td>
<td></td>
</tr>
<tr>
<td>Large-scale 1217 bus model system</td>
<td></td>
</tr>
<tr>
<td>power system controls, 415</td>
<td></td>
</tr>
<tr>
<td>Lbest model</td>
<td></td>
</tr>
<tr>
<td>PSO techniques, 79</td>
<td></td>
</tr>
<tr>
<td>Learning parameter, 61</td>
<td></td>
</tr>
<tr>
<td>Least-cost GEP</td>
<td></td>
</tr>
<tr>
<td>generation expansion, 288</td>
<td></td>
</tr>
<tr>
<td>objective, 286</td>
<td></td>
</tr>
<tr>
<td>Left gap, 115</td>
<td></td>
</tr>
<tr>
<td>Light load level case</td>
<td></td>
</tr>
<tr>
<td>initial electrical power results, 376</td>
<td></td>
</tr>
<tr>
<td>initial thermal power results, 375</td>
<td></td>
</tr>
<tr>
<td>optimal electrical power results, 378</td>
<td></td>
</tr>
<tr>
<td>optimal thermal power results, 377</td>
<td></td>
</tr>
<tr>
<td>Limited tabu search (LTS), 309</td>
<td></td>
</tr>
<tr>
<td>Linear convergence order, 57</td>
<td></td>
</tr>
<tr>
<td>Linear programming (LP)</td>
<td></td>
</tr>
<tr>
<td>load shedding, 139</td>
<td></td>
</tr>
<tr>
<td>problem, 299</td>
<td></td>
</tr>
<tr>
<td>stopping criterion solutions, 140</td>
<td></td>
</tr>
<tr>
<td>Linear quadratic regulator (LQR)</td>
<td></td>
</tr>
<tr>
<td>controller design, 420, 423</td>
<td></td>
</tr>
<tr>
<td>controller results, 425–426</td>
<td></td>
</tr>
<tr>
<td>drum level response, 427</td>
<td></td>
</tr>
<tr>
<td>power response, 426</td>
<td></td>
</tr>
<tr>
<td>pressure response, 426</td>
<td></td>
</tr>
<tr>
<td>Linear ranking selection</td>
<td></td>
</tr>
<tr>
<td>GA basic operators, 34</td>
<td></td>
</tr>
<tr>
<td>Linear scaling, 35</td>
<td></td>
</tr>
<tr>
<td>Linear string point of view, 36</td>
<td></td>
</tr>
<tr>
<td>Linguistic values, 148</td>
<td></td>
</tr>
<tr>
<td>Load</td>
<td></td>
</tr>
<tr>
<td>flow feasibility, 314</td>
<td></td>
</tr>
<tr>
<td>Load</td>
<td></td>
</tr>
<tr>
<td>demand, 355, 358</td>
<td></td>
</tr>
<tr>
<td>and electricity buying-selling prices, 373</td>
<td></td>
</tr>
<tr>
<td>flow algorithm, 245</td>
<td></td>
</tr>
<tr>
<td>flow problem, 478</td>
<td></td>
</tr>
<tr>
<td>forecasting, 358</td>
<td></td>
</tr>
<tr>
<td>growth, 315</td>
<td></td>
</tr>
<tr>
<td>IEEE 14-Bus System, 479</td>
<td></td>
</tr>
<tr>
<td>level cases, 379</td>
<td></td>
</tr>
<tr>
<td>loss, 278–280</td>
<td></td>
</tr>
<tr>
<td>power system vulnerability assessment, 278–280</td>
<td></td>
</tr>
<tr>
<td>production costs, 379</td>
<td></td>
</tr>
<tr>
<td>Load shedding</td>
<td></td>
</tr>
<tr>
<td>LP, 139</td>
<td></td>
</tr>
<tr>
<td>topology, 138</td>
<td></td>
</tr>
<tr>
<td>Local minimal solutions</td>
<td></td>
</tr>
<tr>
<td>minimization problem, 230</td>
<td></td>
</tr>
<tr>
<td>Local optimal solution</td>
<td></td>
</tr>
<tr>
<td>computing, 223</td>
<td></td>
</tr>
<tr>
<td>Local power flow control</td>
<td></td>
</tr>
<tr>
<td>power system controls, 454</td>
<td></td>
</tr>
<tr>
<td>proposed interactive DWCP method, 512</td>
<td></td>
</tr>
<tr>
<td>LOLP. See Loss of load probability (LOLP)</td>
<td></td>
</tr>
<tr>
<td>Long-term memory</td>
<td></td>
</tr>
<tr>
<td>TS, 115–117</td>
<td></td>
</tr>
<tr>
<td>Long-term UC solution, 548</td>
<td></td>
</tr>
<tr>
<td>Look-up table, 290</td>
<td></td>
</tr>
<tr>
<td>Loss of load probability (LOLP), 287</td>
<td></td>
</tr>
<tr>
<td>LP. See Linear programming (LP)</td>
<td></td>
</tr>
<tr>
<td>LQR. See Linear quadratic regulator (LQR)</td>
<td></td>
</tr>
<tr>
<td>LTS. See Limited tabu search (LTS)</td>
<td></td>
</tr>
<tr>
<td>Mahalanobis metric, 64</td>
<td></td>
</tr>
<tr>
<td>Maintenance cost, 356</td>
<td></td>
</tr>
<tr>
<td>Maintenance period, 355</td>
<td></td>
</tr>
</tbody>
</table>
Maintenance scheduling, 26, 354–365
constraints, 355
defined, 354
GA, PSO, and ES implementation, 355–364
maintenance cost, 356
objective function, 359
optimization function, 355
penalty cost, 356–358
problem, 354
problem representation, 360–364
total operating cost, 356
Mapping
geometric interpretation, 269
Markov chain, 140, 141
Mating pool, 370, 371
crossover, 371
GA, 419
MATLAB
command line, 485
GAOT, 476
OPF problem, 485
Maximum wind power (MW), 546
losses, 491
Max-min ant system (MMAS), 92, 96
ACSA, 95–97
MBS. See Model-based search (MBS)
algorithm
MCDM. See Multicriteria decision making
(MCDM)
Measurement, 265
Mega VAR (MVAR) losses, 491
Membership function
genetic adjustment, 167
Meta-heuristic methods
network expansion transmission, 311
Method of self-adaptation, 11
Metropolis algorithm
simulated annealing, 125
MGAP. See Multilevel generalized
assignment problem (MGAP)
MHN. See Modified Hopfield neural
network (MHN)
Middle gap, 115
MIMO. See Multiinput multioutput
(MIMO)
Minimization problem, 228–230
decomposition points, 230
local minimal solutions, 230
Minimization problems, 177
Minimized prediction error entropy wells, 5
Mixed-integer nonlinear optimization
problems (MINLP), 71, 83, 405
MMAS. See Max-min ant system (MMAS)
MO. See Multiobjective (MO)
Model-based predictive control
(MPC), 428
Model-based search (MBS) algorithm, 89
Model identification, 239–241
approximation functions, 242
dynamic load modeling, 239
neural network training, 241–242
pruning vs. growing, 241
short-term load forecasting, 240
Modeling chromosome repair
reactive power planning at distribution
level, 326
Modern heuristic optimization theory,
1–20
evolutionary computation, 3–20
Modification of searching points, 81
Modified Hopfield neural network
(MHNN), 349
Modified IEEE 14 bus system, 410
Modified IEEE 30-bus system, 496
Modified particle swarm optimization
(MPSO), 346, 349
Modified simple genetic algorithm
(MSGA), 320, 324, 326
iteration result, 325
Modus ponens, 149
MOGA. See Multiobjective genetic
algorithm (MOGA)
Monte Carlo simulation, 125
MOO. See Multiobjective optimization
(MOO)
MOPSO. See Multiobjective particle swarm
optimizer (MOPSO)
Movement rule, 551
Moving gap technique, 115
MPC. See Model-based predictive control
(MPC)
MPSO. See Modified particle swarm
optimization (MPSO)
MSGA. See Modified simple genetic
algorithm (MSGA)
Multicogeneration systems
energy flow, 368
Multicriteria decision making (MCDM), 194
Multiinput multioutput (MIMO), 404
Multilevel generalized assignment problem (MGAP), 120
Multiobjective (MO), 404
decision-making, 449
optimization methodologies, 501
optimization techniques, 503–507
constraint method, 504
fuzzy set theorem applications, 505
genetic algorithm, 505
goal programming, 504
interactive procedure, 506
power system controls, 446–449
weighting method, 503
problems, 189
comparing solutions, 193
Multiobjective genetic algorithm (MOGA), 199
fitness computation, 199
Multiobjective optimization (MOO) algorithms, 189
cardinality, 203
elitism, 199
generational distance, 203
hypervolume indicator, 203
spacing, 203
Multiobjective particle swarm optimizer (MOPSO), 202
Multiple conflicting objectives, 448
Multiple_mutations, 361
Multiple-population GAs, 40
Multistage method and directional crossover
GA implementation to ED, 345
Mutating strategic parameters
voltage/VAR control in distribution networks, 552
MUTATION, 81
Mutation
differential evolution, 181–182
EPSO, 551
GA basic operators, 38
method, 441
operation, 419
probability, 478
process, 161
process flowchart, 363
MVAR. See Mega VAR (MVAR) losses
MW. See Maximum wind power (MW)
ND. See Neighborhood digging (ND)
NDlast, 548, 549
Negative diagonals characterization, 109
Neighbor configuration, 110
swapping, 132
swapping elements, 111
Neighborhood, 106
defined, 138
Neighborhood digging (ND), 547
Neighborhood structure
TS, 105–107
Neighbor topology generation, 139
Net present value1 (NPV), 248
Network expansion planning problem
cost of trial configuration, 137
Network expansion transmission, 297–311
coding problem representation, and test systems, 302–303
genetic algorithms, 307–308
hybrid TS/GA/SA algorithm, 310
meta-heuristic methods, 311
simulated annealing, 306
solution techniques, 300–301
static transmission network planning, 297–301
tabu search, 309
test systems complexity, 304–305
Network partition problems
applications, 230
Network reconfiguration for loss reduction
distribution system applications, 245
Neural network feature extraction (NNFE)
power system vulnerability assessment, 268–269
Neural networks (NNs), 241, 264
structure extract features, 268
training, 241–242
Neuro-fuzzy system
structure, 436
New worst compromise value assignation rules, 456, 514
Niched Pareto genetic algorithm (NPGA), 200
Niching methods, 38
NLMIP. See Nonlinear mixed integer problem (NLMIP)
NLP. See Nonlinear problem (NLP)
NN. See Neural networks (NNs)
NNFE. See Neural network feature extraction (NNFE)
Nodal voltages
IEEE 14-Bus System, 479
No free lunch, 13
Nondegeneracy, 211
Non-dominated sorting genetic algorithm (NSGA), 200
Nonlinear mixed integer problem (NLMIP), 298
Nonlinear optimization problems, 76
Nonlinear problem (NLP), 298
Nonparametric NN models, 241
Non-polynomial time (NP-complete), 285
Nonuniform mutation, 477
Normalized geometric selection, 477
North-Northeastern Brazilian system, 305
North-Northeastern P1 Plan, 301
NP-complete. See Non-polynomial time (NP-complete)
NP-iteration (transitions), 119
NPV. See Net present value (NPV)
NSGA. See Nondominated sorting genetic algorithm (NSGA)
Numerical method of trust-tech paradigm, 221–260
DDP computing, 222
exit point computing, 222
local optimal solution, 223
local optimal solution computing, 222–223
Numerical schemes
trust-tech paradigm, 227
Numerical solution acceleration method virtual GA, 175
OA/ER. See Outer approximation with equality relaxation (OA/ER)
Objective function
maintenance scheduling, 359
Objective function values, 350
variation, 539
Object oriented programming (OOP), 442
Object parameters (OP), 49
ODE. See Ordinary differential equation (ODE)
Oloss', 318
OLTC. See On-load tap changer (OLTC)
O&M. See Operating and maintenance (O&M) cost
OMNR. See Optimal multiplier Newton-Raphson (OMNR)
One-point crossover, 36
On-load tap changer (OLTC), 405
OOP. See Object oriented programming (OOP)
Oover', 318
OP. See Object parameters (OP)
Operating and maintenance (O&M) cost, 287
Operating point, 279
Operating time of units, 381
Operation cost minimization
power system controls, 454
OPF. See Optimal power flow (OPF)
Optimal control
IEEE 14 Bus System, 411
Optimal multiplier Newton-Raphson (OMNR), 457, 516
Optimal phase angles and compensators, 498
Optimal power flow (OPF), 409, 471, 502
under contingent condition with line capacity limit, 488
FACTS devices, 488–497
loss minimization, 488
objectives, 491
problem
GA for solving, 483–488
MATLAB command line, 485
Optimal protection and switching devices placement
distribution system applications, 246
Optimal scenario
FACTS devices, 463, 520
Optimal solution
6-bus system with generation rescheduling, 304, 305
Garver’s system, 305
Optimal solution (Continued)

TSP, 133
Optimal strategic parameter, 54
Optimization function, 355
maintenance scheduling, 355
power systems applications, 237
process, 497
Optimization problem
using DE, 185
using GA with elitism, 185
Optimized cost, 366
Optimize neural networks, 9
Optimum evolution strategies, 53
Ordinal-based selection, 33
Ordinal selection scheme advantages, 34
Ordinary differential equation (ODE), 227, 232
Originals membership functions, 163
Other people’s experiences, 72
Outer approximation with equality relaxation (OA/ER), 405

PAES. See Pareto archives evolution strategy (PAES)
Parallel genetic algorithms, 39, 40
Parallelism
evolutionary computation, 8
Parallel simulated annealing, 140–142
clustering algorithm, 142
division algorithm, 141
Parallel virtual machine (PVM), 408
Parameters
cogeneration scheduling, 379
FACTS devices, 510
Parameter sensitivity analysis
IEEE 14-Bus System, 412
Parameters estimation
GA basic operators, 38
Parameter value selection
evolution strategies, 56
Pareto, Vilfredo, 191
Pareto archives evolution strategy (PAES), 201
Pareto dominance, 191
Pareto front
biobjective optimization problem, 192
using population-based techniques, 198

Pareto multiobjective optimization, 189–205
attainment function method, 204
classic methods, 194–195
common population-based MO algorithms, 200–201
comparison methodologies, 203–204
concepts, 191–192
dominance ranking, 204
e-constraint, 195
generic formulation, 191
goal programming, 195
intelligent methods, 196–202
modern methods, 202
objective, 202
objectives, 193
performance analysis, 202–204
population-based MOO solvers, 196–200
principles, 190–193
quality indicators, 203
solution approaches, 194–195
weighted aggregation, 194
Pareto optimality, 191
Particle reproduction
EPSO, 552
Particle swarm optimization (PSO), 71, 201, 337, 403, 525
algorithms, 550
application, 82
bus system (112), 414
convergence characteristics, 414
defined, 274
vs. EPSO, 554–555
expansion for MINLP, 406
flowchart, 75
implementation
flowchart, 364
maintenance scheduling, 355–364
implementation to ED, 346–348
constraints handling, 346–347
dynamic space reduction strategy, 348
with smooth/nonsmooth cost function, 349–353
modified, 346
performance, 556
states evaluated each iteration, 415
techniques, 71–89
APSO, 79–80
background, 72
CFA, 77
discrete, 76
EPSO, 81
HPSO, 78
Lbest model, 79
MINLPs, 77
original, 72–74
research, 82
variations, 76–81
Particle swarm technique
IEEE 14 bus system, 409–411
large-scale 1217 bus model system, 415
numerical examples, 409–415
power system controls, 404–416
practical 112 bus model system, 412–414
problem formulation, 406
PSO expansion for MINLP, 406
state variables, 405
voltage security assessment, 407
VVC problem formulation, 405–406
VVC using PSO, 408
Path relinking, 103, 117
TS, 119
Payoff function for optimization, 7
Pbest, 363
PCPDIPLP. See Predictor-corrector primal-dual interior point linear programming (PCPDIPLP)
Penalty cost
maintenance scheduling, 356–358
Penalty term, 31
Perfect crystal, 124
Personal best, 201
Personal experiences, 72
PFC. See Power flow control (PFC)
Phase shifter
effect, 494
Phenotype
defined, 44
Phenotypic representation, 44
Pheromone decay parameter, 96
Pheromone trail, 90
constraint, 97
PI. See Proportional integral (PI)
PID. See Proportional-integral-derivative (PID) compensators
Piecewise quadratic cost function
generator, 339
PIM. See Power injection model (PIM)
Pmutate, 364
Point crossover, 66
Population-based meta-heuristics, 194
Population-based MOO solvers
pareto multiobjective optimization, 196–200
Population-based optimization technique, 171
Population size
GA terms, 474
Positive feedback
ACSA, 98
Power and pressure ramp test
response of drum pressure, 442
response of electrical power, 443
Power and pressure step change
response of drum pressure, 443
response of electrical power, 444
Power flow constraints, 406
Power flow control (PFC), 445, 449
equivalent circuit, 494
membership, 455, 513
model of FACTS devices
formulated MO optimization model, 508–510
power system controls, 450–453
PIM, 451, 509
targets of FACTS devices, 502
UPFC, 488
Power flows for branches, 498
Power generation limits, 486
Power injection model (PIM), 450, 494
based FACTS model, 507
FACTS devices, 451, 509
PFC, 451, 509
Power losses
and generation, 498
Power plant controller design with GA
boiler-turbine model, 419
GA control system design, 420–423
GA design results, 423–425
GA/LQR controller results, 425–426
GA/PI controller results, 423–424
LQR controller design, 423
PI controller design, 420–422
power system controls, 417–427
Power plant model
  power system controls, 430
Power scaling, 35
Power system complexity
  power system vulnerability assessment, 264
Power system controls, 403–461
  applied fuzzy compromise programming, 453
  applies power flow control model, 453
  boiler-turbine model, 419
  compromise programming, 447
  control input optimization, 431–434
  controller implementation, 442–443
  control variables, 450–452
  EPSO, 427–444
  formulated MO optimization model, 449–450
  fuzzy set theory application, 448
  GA control system design, 420–423
  GA design results, 423–425
  GA/LQR controller results, 425–426
  GA/PI controller results, 423–424
  genetic algorithm, 448
  goal programming, 447
  IEEE 14 bus system, 409–411
  implementation, 457
  intelligent predictive controller structure, 428–429
  interactive compromise programming, 444–449
  interactive procedure, 449
  large-scale 1217 bus model system, 415
  local power flow control, 454
  LQR controller design, 423
  MO optimization techniques, 446–449
  numerical examples, 409–415
  numerical results, 457
  operation cost minimization, 454
  particle swarm technique, 404–416
  phase 1 model formulation, 456
  phase 2 noninferior solution calculation, 456
  phase 3 scenario evaluation, 456
  PI controller design, 420–422
  power flow control model of FACTS devices, 450–453
  power plant controller design with GA, 417–427
  power plant model, 430
  practical 112 bus model system, 412–414
  problem formulation, 406
  proposed interactive DWCP method, 453–454
  proposed interactive procedure and worst compromise displacement, 455–456
  PSO expansion for MINLP, 406
  rule generation and tuning, 438–441
  self-organized neuro-fuzzy identifier, 435–437
  state variables, 405
  state variables treatment, 408
  voltage security assessment, 407
  VVC algorithm using PSO, 408
  VVC problem formulation, 405–406
  VVC using PSO, 408
  weighting method, 447
Power systems applications, 237–249
  approximation functions, 242
  control, 242–243
  distribution networks prioritizing investments, 247
  distribution system applications, 244–246
  dynamic load modeling, 239
  examples, 243
  model identification, 239–241
  network reconfiguration for loss reduction, 245
  neural network training, 241–242
  optimal protection and switching devices placement, 246
  optimization, 237
  pruning vs. growing, 241
  short-term load forecasting, 240
Power system scheduling, 337–398
  economic dispatch, 337–354
  GA implementation to ED, 339–345
  problem, 337–345
Power system vulnerability assessment, 261–280
  anticipated load loss, 278–280
  challenges, 264–280
  control, 263
INDEX

581

distance from border, 277
enhanced particle swarm optimization method, 274
evolutionary computation method, 272–273
feature selection, 265–270
Fisher’s linear discriminant, 266–267
gradient method, 272
NNFE, 268–269
power system complexity, 264
support vector machine feature-extraction, 270
VA on-line speed, 265
vulnerability border, 270–274
vulnerability index selection, 276–280
Power unit identifier
training process, 439
Power-voltage (P-V) curve, 405
IEEE 14 bus system, 413
Practical 112 bus model system
power system controls, 412–414
Prediction horizon, 428
predictive control system, 429
Predictive control system
prediction horizon, 429
Predictor-corrector primal-dual interior point linear programming (PCPDIPLP), 457, 516
Premature convergence
fitness function, 32
Premise matrix, 436
Pressure ramp test
response of drum pressure, 442
response of electrical power, 443
Pressure step change
response of drum pressure, 443
response of electrical power, 444
Prioritizing, 248
Probabilistic model, 89
Problem-solving with no known solutions evolutionary computation, 11
Progress coefficient, 56
Progress rate, 50
Prohibited operating zone, 340
Projection method, 341
Proportional integral (PI)
controller design, 420–421
controller results, 423–424
controller structure, 421
drum level response, 425
gains training schedule, 421
pressure response, 424, 425
Proportional-integral-derivative (PID) compensators, 403
Proportional selection
basic operators, 35
Proportionate selection, 33
Proposed interactive displaced worst compromise programming method, 511–512
applied fuzzy CP, 511
local power flow control, 512
operation cost minimization, 512
Proposed interactive procedure with WC displacement, 513–514
phase 1 model formulation, 513
phase 2 noninferior solution calculation, 514
phase 3 scenario evaluation, 514–515
Pruning vs. growing
power systems applications, 241
Pseudo-random-proportional rule, 96
PSO. See Particle swarm optimization (PSO)
Pure phenotypic, 45
P-V. See Power-voltage (P-V) curve
PVM. See Parallel virtual machine (PVM)
Q-learning algorithms, 386, 392, 393, 395, 399
IEEE 136-Bus System, 398
Quadratic assignment problem (QAP), 96, 120
Quadratic cost function, 350
Quasi-stability boundary characterization, 219
Quasi-stability region, 213
Quasi Steady-State (QSS), 407
Queen problem
attribute storage, 112
coding, 111
Random dynamic tabu tenure, 115
Rated capacity, 355
Rate of progress toward the optimum, 56
Reactive compensation placement, 26
Reactive power control problem
IEEE 14-bus system, 390
IEEE 136-Bus System, 398
Reactive power generations, 487, 489–490, 493
Reactive power planning distribution level, 326–329
evolutionary programming, 327–329
modeling chromosome repair, 326
Reactive power planning generation-transmission level, 320–326
benders decomposition of reactive power planning problem, 321–322
IEEE 30-bus system, 324–325
solution algorithm, 323
Reactive tabu search (RTS), 405
bus system (14), 412
bus system (112), 412
convergence characteristics, 414
states evaluated each iteration, 415
Real ants behavior, 90
Real power balance constraint, 381
Real power operating limits of generating units, 381
Real-valued encoding, 37
Real-world function optimization problem, 7
Recency-based tabu search functions and strategies, 110–111
Recombination features, 65–66
Reduced practical system, 458, 516
Reduced surrogates, 37
implementation, 37
Reference solutions, 119
Region of attraction, 213
Regularity, 211
Rejection constraints, 245
Reliability, 314
Repair constraints, 245
REPLICATION, 81
Replication
EPSO, 551
Representations computational equivalence current developments, 14–15
REPRODUCTION, 81
Reproduction
with emphasis, 16
EPSO, 551
operation GA, 419
VVC in distribution networks, 551
Residence frequency technique, 116
Resource constraints, 357
cost multiplier, 359
Restricted mating, 39
RHS. See Right-hand side (RHS)
Right gap, 115
Right-hand side (RHS), 73
Right-of-ways, 136
Ring representation, 36
Robustness, 314
Roulette representation, 162
Roulette wheel stochastic selection of crossover method, 292
Roulette wheel selection, 16
Routes after training, 166
without training, 165
RTS. See Reactive tabu search (RTS)
SA. See Simulated annealing (SA) algorithm
SC. See Static condensers (SCs)
Schaffer’s vector-evaluated genetic algorithm, 197
Scheduled total capacities comparison, 384
Scheduling objective, 367
Schema theorem in presence of random variation current developments, 16
Schwefel’s rule, 56, 57
Searching concept agents in solution space, 74
Searching point modification, 74
Searching process correlated directions, 64
HPSO, 80
Search pattern induced in two different individuals, 58
Search space GA terms, 473
Second-order progress coefficient, 56
Security levels parameters, 271
SELECT, 81
Selection by-fitness-function principle, 44
CARE model in Crete, Greece, 544
EPSO, 551
process GA, 418
proportionate selection, 34
Self-Adaptation in ES, 58
SelfBest, 274
Self-optimization evolutionary computation, 10
Self-organized neuro-fuzzy identifier
power system controls, 435–437
SEP. See Stable equilibrium point (SEP)
Sequential fan candidate list technique, 114
Series compensator limits, 497
Series compensator line, 495
Series encoding, 340
Series-parallel identification, 435
Seven-queens problem, 109
SGA. See Simple genetic algorithms (SGA)
Short-term load forecasting power systems applications, 240
Short-term memory, 110
ShRs. See Shunt reactors (ShRs)
Shunt capacitor compensations, 487, 489–490, 493
Shunt reactors (ShRs), 403
Sigma truncation, 35
SIMD. See Single instruction, multiple data (SIMD) computers
Simple genetic algorithms (SGA), 292, 320, 348, 476, 528
best run, 535
iteration result, 325
Simplified Azores Islands test system single-line diagram, 327
Simulated annealing (SA) algorithm, 26, 123–143, 172
applications, 143
clustering algorithm, 142
cooling rate determination, 130
cooling schedule, 127–130, 133, 140
cost function, 132
defined, 123
division algorithm, 141
initial solution, 136–137
initial temperature determination, 128
metropolis algorithm, 125
neighborhood structure, 138
network expansion transmission, 306
Nk determination, 129
objective function, 139
parallelizing, 141
parallel simulated annealing, 140–142
principles, 125–126
problem coding, 131, 136
stopping criterion, 130
transmission network expansion problem, 134–140
traveling salesman problem, 131–134
Simulation results, 366
comparison, 351, 352, 353
Single instruction, multiple data (SIMD) computers, 39
Single-objective (SO) function, 503
optimization problems, 189
Single-population master-slave GAs, 40
Slow finishing fitness function, 32
SO. See Single-objective (SO)
Solidification of crystals, 124
Solution algorithm flowchart, 319
reactive power planning at generation-transmission level, 323
Solution encoding characteristics, 247
Solution space attractive area, 78
searching concept, 74
Solution techniques network expansion transmission, 300–301
SP. See Strategy parameters (SP)
Spacing
MOO, 203
SPEA. See Strength pareto evolutionary algorithm (SPEA)
Spherical model, 63
Spinning reserve constraint, 356, 381
requirement, 355
SSSC. See Static synchronous series compensator (SSSC)
Stability boundary, 217
Stability region (or region of attraction), 213
INDEX

Stable equilibrium point (SEP), 212, 216, 217, 220, 222
Starting point features, 67
STATCOM. See Static synchronous compensator (STATCOM)
State variables
  power system controls, 405, 408 treatment, 408
Static condensers (SCs), 403
Static synchronous compensator (STATCOM), 452, 509
Static synchronous series compensator (SSSC), 452
Static transmission network planning
  network expansion transmission, 297–301
Static VAR compensator (SVC), 243, 452, 491, 509
StGA. See Straightforward genetic algorithm (StGA)
Stochastic crossover, elitism, and mutation generation expansion, 291
Stochastic tournament, 60
Stopping criterion
  LP solutions, 140 simulated annealing, 130
Stopping rule
  characteristics, 247
  GA terms, 478
Straightforward genetic algorithm (StGA), 548
GAND, 550
Strategic oscillation, 103
TS, 119
Strategy parameters (SP), 49
Strength pareto evolutionary algorithm (SPEA), 199
elitism, 201
Strict complementarity, 212
Substring structure, 289
Successive filter strategy technique, 114
Support vector machines (SVM), 270 feature-extraction, 270
SVC. See Static VAR compensator (SVC)
SVM. See Support vector machines (SVM)
SVS. See Synchronous voltage sources (SVSs)
Swapping
  elements, 111 neighbor configuration, 111, 132
  TSP, 133
Swarm intelligence, 71
Swarm model, 71
Switched capacitors, 527
Switching coding scheme, 542
Symmetrical TSP, 125
Synchronous voltage sources (SVSs), 450, 508
System planning, 285–329
generation expansion, 285–296
Tabu-active selected attributes, 110
Tabu search (TS), 101–119
  algorithm, 112–115
  algorithm transitions, 113
  applications, 119
  aspiration criteria, 115
  candidate list strategies, 114
coding and representation, 104
defined, 27, 101
diversification, 117
element, 105
  frequency-based memory, 116
  functions and strategies, 110–119
  intensification, 116
  long-term memory, 115–117
  neighborhood characterization, 108–110
  neighborhood structure, 105–107
  network expansion transmission, 309
  overview, 101–102
  path relinking, 119
  problem formulation, 103
  recency-based, 110–111
  strategic oscillation, 119
  tenure, 114
  transition, 104
TCDP. See Tunnel-constrained dynamic programming (TCDP)
TCPS. See Thyristor-controlled phase-shifter (TCPS)
TCSC. See Thyristor-controlled series capacitor (TCSC)
Temperature determination
  simulated annealing, 128
Temperature parameter, 27
Unit system. See Bus system (6)
Unstable equilibrium point, 212, 218
UPFC. See Unified power flow controller (UPFC)
Uptime of units, 381

VA. See Vulnerability assessment (VA)
Vacancy defect, 124
Value plus, 114
Valve
cost function, 339, 491
generating units, 491
point effects, 351, 491
point loading, 491
VAR. See Volt-Ampere- Reactive (VAR) compensation
Variable cooling rate, 130
Variation, 46
VC. See Vulnerability control (VC)
Vector-evaluated genetic algorithm (VEGA), 197
biobjective minimization problem, 198
Vectors, 72, 73
VEGA. See Vector-evaluated genetic algorithm (VEGA)
Vehicle parking problem, 153
Vehicle routing problem (VRP), 120
Very-large-scale integration (VLSI), 174
placement, 143
VI. See Vulnerability index (VI)
Virtual genetic algorithm
numerical solution acceleration method, 175
Virtual population-based acceleration method, 175
VLSI. See Very-large-scale integration (VLSI)
Voltage constraints, 406
Voltage level feasibility, 314
Voltage profile performance, 537
Voltage quality, 314
Voltage security, 406
Voltage security assessment (VSA), 405
power system controls, 407
Voltage source model
UPFC, 451
Voltage/VAR control (VVC), 403, 407, 408
algorithm using PSO, 408
EPSO, 550–558
applying in distributed generation network management, 557
hybrid approach justification, 550
merits, 553
model, 554
mutating strategic parameters, 552
reproduction and movement rule, 551
test function, 554–555
and loss reduction in distribution networks, 403, 550–558
problem formulation, 405–406
state variables treatment, 408
using PSO, 408
Volt-Ampere-Reactive (VAR) compensation
blocks, 385
operating space of constrained variables, 397
VRP. See Vehicle routing problem (VRP)
VSA. See Voltage security assessment (VSA)
Vulnerability assessment (VA), 263
on-line speed, 265
Vulnerability border
power system vulnerability assessment, 270–274
Vulnerability border and margin, 277
Vulnerability control (VC), 263
Vulnerability index (VI), 271
NN structure, 270
selection, 276–280
VVC. See Voltage/VAR control (VVC)
WASP. See Wien Automatic System Planning Package (WASP)
Weighted aggregation
pareto multiobjective optimization, 194
Weighting method
multiobjective optimization techniques, 503
power system controls, 447
Wien Automatic System Planning Package (WASP), 287, 292, 297
Ysidro, Francis, 191
Zadeh, Lofti A, 147
Zero mean multivariate Gaussian perturbation, 61