## INDEX

8 A-c tripping, 335 Angle-impedance relay, 79 for tripping on 1088 of synchronism, Angle of maximum torque, adjustment,, 57 of power relays, 52, 55 of shortcircuit relays, 55 Arcs, effect on distance relays, 345 resistance, Arc - furnace - transformer protection, 270 ASA accuracy classification,, of current transformers,, 121 of potential transformers, 133 Attenuation, carrier-current, 378 Automatic reclosing, see Reclosing, automatic Auxiliaries,, station, protection of, 229 see also Motor protection Back-up relaying, defined, 6 effect of intermediate current sources, 347 for bus protection, 275, 291 generator external fault,227 reversed third zone, 175, 349 transformer external fault, 264, 268 with pilot relaying, 378, 386 Blind spot in pilot relaying, 94 Blinder with directional-comparison relaying, 386, 390 Blocking pilot, 88, 91 Blocking terminal, with a-c wire-pilot relaying, 375

Abnormal conditions other than short circuits,,

with directional comparison pilot relaying, 392 with phase-comparison pilot relaying, Broken-delta connection, burden calculation, for detecting grounds in ungrounded systems,, 320 for polarizing directional ground relays, of capacitance potential devices, 135, 140 Buchholz relay, 281 Burden, current-transformer, 114 potential transformer, 133 Bus protection, automatic reclosing, 292 by back-up relays, 275, 291 circuitbreaker by-psasing, 292 combined power transformer and bus, 287 current differential with overcurrent relays, 278 current differential with overvoltage relays, 288 current differential with percentage relays, 284 directional comparison, 277 fault bus,, 275 grounding secondaries of differentially connected CT's, 291 partial-differential, 282 ring-bus,, 290 testing, 292 voltage differential with linear cou, 284

Bushing potential device, see Capacitance potential device

Capacitance potential device, broken burden, 140 comparison with instrument PT's, 144 couplingcapacitor insulation coordination, 142 effect of overloading, 138

Capacitance potential device, equivalent circuit, 135 non-linear burdens, 139 standard accuracy, 137 standard rated burdens, 136

Capacitor, series, effect on distance relaying, 367

Capacitor tripping, 335

Carrier-current attenuation, 378

Carrier-current-pilot relaying, see Pilot relaying, carrier-current

Circuit breaker, by-passing, 292 standard capacities, 3

Circulating-current pilot relaying, 92, 94

Cold-load pickup, 334

Cold-load restoration, 334

Compensated voltage, see Transformer compensation

Constant-product characteristic, 38

Contact definitions, 17

Contact races in pilot relaying, 91

Continuous pilot, 109

Control spring, 17

Conventions, vector, 53

Corrosion, effect of polarity on, 19

Coupling-capacitor description, 134

Coupling-capacitor insulation coordination, 142

Coupling-capacitor potential device, Bee Capacitance potential device

Current-balance relay, directional type, 62 for line protection, 330 overcurrent type, 58

Current biasing, for mho relay, 82 for offset impedance relay, 77 to avoid distance-relay misoperation on arcs, 346

Current compensation for ground distance relays,, 360

Current switching for distance relays, 368

Current transformers,, accuracy calcula, 113
ASA accuracy classification, 121 burden, 114
for generator differential relaying, 198
ratiocorrection-factor curves,, 116 secondaryexcitation curves,, 117 grounding the
secondaries of differentially connected CT's,
291 overvoltage in secondary, 124 polarity
and connections, 126 proximity effect, 126

Current transformers, requirements for pilot relaying, 377 secondary leakage reactance, 117, 119, 120 transient errors, 124, 278, 318 types, 113 zero-phase-sequencecurrent shunt, -130, 249

D-c offset, effect on induction relays, 32, 39 overreach of distance relays, 82, 350 overreach of overcurrent relays, 308 time constant, 279

D-c relays, single-quantity, 22 directional, 24, 49

Differential relays, 63 see also Percentagedifferential relays

Directional-comparison relaying, for bus protection, 277 principle of operation, 106 see also Line protection with pilot relays

Directional control, of electromagnetic relays,, 23 of single-quantity induction relays,, 32,57,310,313

Directional-overcurrent relay, 57

Directional relays,, a-c types, 33, 52 connections,, 52 power, 52 short circuits, 56 characteristics on R-X diagram, 74 d-c types,, 49 use of shunts, 52 effect of mutual induction on ground relays, 393 electromagnetic-attraction type, 24 ground-relay polarization, 151, 326 misoperating tendencies, 314 negative-phase-aequence type, 330 operating characteristics,, 37 response of polyphase relays to positive and negative phase sequence,, 183 response of ainglephase relays to short circuits,, 187

Distance relays,, current and voltage switching, 368 effect of power swings and lose of synchronism,, 181 effect of wye-delta transformer between relay and fault, 172 electronic type, 369 ground-relay connections, 360 impedance seen during faults,, 167

Generator protection, overvoltage, 217 potential-transformer fuse blowing, 228 prime mover, 230 station auxiliary, 229 stator overheating, 216 stator short circuit, 195 calculation of CT errors, 198 ground faults, sensitive, 208 ground faults in unit generators, 209 overcurrent relays for, 215 turn-to-turn faults, 204 unbalanced phase currents, 221 vibration, 225

Ground-distance-relay connections, 360

Ground-fault neutralizer, effect on line relaying, 321 to mitigate the effect of a fault, 2

Grounding protective relay for trans former protection, 263

Ground preference, 91, 108

Ground resistance, 303

Grounding-tranaformer protection, 268

Hsrmonic-current restraint, for distance relays,, 357 for transformer differential relays, 257

Holding coil, 18

Impedance diagram, see R-X diagram

Impedance relay, characteristic on R-X diagram, 72 for line protection, 340 general, 70 see also Distance relays

Induction-cup and induction-loop structures, 30, 31

Induction-type relay, directional, 31 general characteristics,, 26 single-quantity, 31 structures, 29 torque production, 26

Insulating transformer for pilot-wire circuits,, 98

Intermittent pilot, 109

Line protection with distance relays,, adjustment of distance relays,, 341 area, effect of, 345 blocking tripping on 1088 of synchro, 304 choice between impedance, reactance, and mho,, 340 connections of ground distance relays,, 360

Distance relays,, use of low-tension voltage, 145, 148

see also Line protection with distance relays

Distribution-circuit protection, see Line protection with overcurrent relays

Drop-out defined, 17

Electric arc-furnace-transformer protection, 270

Electromagnetic-attraction relay, directional, 24

general characteristics,, 16 single-quantity, 22

Electronic relay, directional comparison pilot, 396

distance, 369

Evaluation of protective relaying, 12

Expulsion protective gaps, effect of, on distance relays, 367

External-fault back-up relaying, see Back-up relaying

Fail ures,, electrical, see Faults

False residual current, 318

Fault bus, 275

Faults, mitigation of effects of, 2 prevention of, 2 probability of, effect on practice, 11 see also Short circuits

Fire, protection against, 230

Fire-pump-motor protection, 230

Footing resistance, tower-, 303

Frequency, compensation of relays for changes in, 49

effect on induction relays,, 32, 39

Frequency-converter protection, see Generator protection

Fundamental principles of protective relaying, 4

Fuse, coordinating with a, 335

Fuse blowing, potential-tranaformer, effect on distance relays,, 361

effect on generator relays,, 228

Generator protection, bearing overheating, 228

external-fault back-up, m field ground, 218

loss of excitation, 223

1088 of synchronism,, 218 miscellaneous,, 228

motoring, 225

open circuits,, 215 over excitation,, 225 over speed,, 226

Line protection with distance relays, current and voltage switching, 368 expulsion protective gaps, effect of, 367 fuse blowing, effect of, 361 electronic relays, 369 intermediate current sources, effect of, 347 low-tension current, use of, 356 low-tension voltage, use of, 352 magnetizing inrush, effect of, 359 overreach, 351, 360 purposeful tripping on loss of synchronism, 361 reclosing, automatic, 366 series capacitor, effect of, 367 see also Distance relays

Line protection with overcurrent relays, a-c and capacitor tripping, 335 adjustment of ground vs. phase re lays, 316 adjustment of inverse-time-overcur rent relays, 297 arc and ground resistance, 302 directional feature, 310 fuses, coordination with, 335 ground faults in ungrounded systems, detection of, 319 ground-fault neutralizers, effect of, 321 instantaneous overcurrent relays,, use of, 306 inverseness,, choice of, in relay char acteristics, 305 limiting ground-fault-current magni tude, effect of, 317 loop circuits,, effect on relay adjust, 303 misoperation prevention of aingle directional-overcurrent re during ground faults, 314 negative-phase sequence ground di

rectional relays,, 330 open phases, effect of, 323, 325 overreach of instantaneous overcur rent relays,, 308 polarizing ground-relay directional unite, 326 reclosing, automatic, 333 restoration of service after prolonged outage, 334 single-phase vs. polyphase directional relays,, 313 transient CT errors, 318 two vs. three relays for phase-fault protection, 311

Line protection with overcurrent relays, see also Overcurrent relays

Line protection with pilot relays, a-c wire-pilot relaying, 374 back-up protection, 378 CT requirements, 377 multi terminal lines, 375 sensitivity, 374 see also Pilot relaying, a-c wire-; Pilot relaying, d-c wire relaying, attenu ation, 378 sleet detection, 379 supervision, automatic, 378 combined phase- and directional com parison, mutual induction, effect on ground relays, 393 when to use, 392 directional comparison, electronic, 396 low-tension voltage, use of, 386 multi terminal lines, 387 sensitivity, 386 transients,, effect of, 392 when to use, 386 see also Pilot relaying, carrier-cur, 393 phase comparison, back-up protec tion, 386 multi terminal lines, 382 sensitivity, 381 when to use, 380 see also Pilot relaying, carrier-cur

rent reclosing, high-apeed,, 399 when to use pilot relaying, 373

Line trap, 100 Linear couplers, 284 Load shedding, 334, 363

Locking in, with generator differential relaying, 202 with transformer differential relaying, 251

Loss-of-excitation protection, 223 Loss-of-field protection, 223

Loss of synchronism, characteristics on RX diagram, 177 derivation of relay current and voltage, 176 effect on distance relays, 181 generator protection, 218 trip-blocking relay, 304, 390 tripping relay, 361

Low-tension current for distance relays, 356

Low-tension voltage, for directional relaying, 386 for distance relaying, 148, 352 general, 145

Magetizing-current inrush, effect on distance relays, 359 effect on transformer differential relays, 254 in parallel transformer banks, 259

Maximum torque, angle of, adjustment, 57 power relays, 52, 55 short-circuit relays, 55

Memory action, described, 83 effect of voltage source location, 144

Mho relay, characteristics on R-X diagram, 81 for line protection, 340 operating characteristic, 80

Microwave-pilot relaying, see Pilot relaying, microwave

Minimum pickup of directional relays,, 38

Mixing transformer for wire-pilot relaying, 96

Modified-impendance relay, 77

Motor protection, field ground, 237 fire-pump, 230 1088 of excitation, 237 1088 of synchronism, 236 rotor overheating, 236 stator overheating, 232 stator short circuit, 230 unattended motors,, 230 under voltage,, 237

Multiterminal-line protection, with a-c wire-pilot relaying, 376 with directional-comparison pilot relaying, 387 with phasecomparison pilot relaying, 382

Mutual induction, effect of, on direc relays,, 393 from power circuit to pilot wires,, 88

Neutralizing transformers for wire-pilot circuits,, 99

Normally blocked trip circuit, 109

Open phase, effect of, on directional relays, 323, 325 equivalent circuits for, 323 protection of generators against, 215

Operating principles,, basic, electromagneticattraction relays,, 16

Operating principles, directional type, 24 singlequantity type, 22 induction relays: directional type, 33 singlequantity type, 31

Operation indicator, 17

Operator vs. protective relays, 11

Opposed-voltage pilot relaying, 92, 95

Out of step, see Loss of synchronism

Overcurrent relays, combination of instantaneous and time delay, 49 pickup or reset, 45 time delay, 45, 46 see also Line protection with overcurrent relays

Overreach, of distance relays, 82, 350, 351 of

instantaneous overcurrent relays, 308

Over travel,, defined, 48 effect of, on overcurrent-relay adjustment, 301

Overvoltage, in CI secondaries, 124 see also Generator protection

Overvoltage relays, pickup or reset,, 45 time delay, 45, 46

Percentage-differential relays, description, 65 for bus protection, 284 for generator protection, 195 for transformer protection, 241 locking-in for internal faults,, 202, 251 product restraint, 204 variable percent slope, 187, 203

Petersen coil, see Ground-fault neutralizer

Phase-comparison relaying, principle of operation, 101 see also Line protection with pilot relays

Pilot relaying, circulating current, 92, 94 general, 86 line protection, 373, 374 opposed voltage, 92, 95 pilot-wire protection, 98 pilot-wire requirements, 97 pilot-wire supervision, 97 remote tripping, 97 see also Line protection with pilot relays

Pilot relaying, carrier-current-, directional comparison, 106 general, 86 intermittent or continuous, 109 phase comparison, 101 pilot described, 100 supervision of pilot channel, 378 see also Line protection with pilot relays;

Pilot relaying,-d-c wire-, basic principles, 89 description of pilot 86

Pilot relaying, micro-wave-, description of channel, 397 general, 86, 101, 396 remote tripping, 398 see also Line protection with pilot relays

Pilot relaying, principles of, ground preference, 91 purpose of a pilot, 87 sensitivity levels, 91, 106 tripping and blocking pilots, 88, 90

Polarizing quantity, of a-c directional relays' 37 of d-c directional relays, 61 of directional units of ground relays, 151, 326

Polyphase directional relays, advantages and disadvantages, 313 response to positive- and negative volt-amps, 183

Potential device, see Capacitance potential device

Potential transformers, accuracy, 133 connections, 146 effect of fuse blowing, on distance relaying, 361 on generator relaying, 228 low-tension voltage for distance relays, 148

Power-balance relaying for line protection, 330

Power-rectifier-transformer protection, 271

Power swings, see Loss of synchronism

Power transformer and autotransformer protection, external-fault backup, 264 gasaccumulator and pressure relays, 261 grounding protective relay, 263 overcurrent relaying, 261 percentagedifferential relaying, 241 CT accuracy requirements, 251 CT connections, 242 CT ratios, 250 magnetizing inrush, effect of, 254 parallel banks, 258 percent slope, choice of, 252 two-winding relay for threewinding transformer, 252 zero-phasesequence-current shunt, 249 remote tripping, 263

Primary relaying defined, 4

Product restraint for generator differential relays, 204

Protective relaying, evaluation of, 12 function of, 3 functional characteristics of, 9 fundamental principles of, 4

Ratings, relay, contact, 43 current and voltage,

42 holding coil, seal-in coil, and target, 43

Ratio correction factor, see Current transformers; Voltage trans formers

Reactance relay, characteristic on R-X diagram, 79 operating characteristic, 78 partial-differential bus protection, 282 see also Line protection with distance relays

Reclosing, automatic, affected by remote tripping, 367 effect on blocking-terminal pilot equipment, 376 mitigation of fault effects, 2 of bus breakers,, 292 single-phase switching, 399 synchronism check, 333, 366 with distance relaying, 366 with overcurrent relaying, 333 with pilot relaying, 399

Rectifier-transformer protection, 271

Regulating-transformer protection, ex fault back-up, 208 in-phase type, 265 phase-shifting type, 267

Reliability, a functional relay characteristic, 9

Remote tripping, by carrier current, 384 by microwave, 398 by pilot wire, 97 for powertransformer protection, 263 frequency-shift system, 264

Replica-type relays, for generator protection, 216 for motor protection, 232, 235

Reset, adjustment of, 19 defined, 17 ratio to pickup, electromagnetic relays, 22 induction relays, 32 time of induction relays, 33, 49

Reversed third zone, for back-up with carrier pilot, 349 where a line includes a transformer, 175

R-X diagram, los-of-synchronism char , 176 appearance to distance relays,, 181 principle of, 72, 156 short-circuit characteristics, 160 appearance to distance relays,, 167 wyedelta transformer between relay and fault, 172

superposition of relay and system characteristics, 157

Seal-in coil or relay, 18

Secondary excitation curves,, 117

Selectivity, a functional relay characteristic, 9

Sensitivity, a functional relay char , 9 levels of blocking and tripping for pilot relaying, 91, 105, 386

Shaded-pole structure, 29

Short circuits, derivation of relay current and voltage, 160 impedance seen by distance relays,, 167 table of currents,, 164 table of voltages,, 165 see also Faults

Single-phase switching, 399

Sleet-accumulation detection with carrier current, 379

Speed, a functional relay characteristic,

Split-phase relaying, combined with percentage differential, 207

for generators, 204

Stability, system, benefited by protective relaying, 12

Step-voltage-regulator protection, 268

Supervision, automatic, of carrier channel, 378

of pilot-wire circuits, 90, 97

Synchronism check with automatic reclosing, 333, 366

Target, 17

Telephone-circuit restrictions, 97

Testing, relay, field, 10 manual, 10

Time characteristics, adjustment of, 45

definitions,, 19 of d-c directional relays, 52 of electromagnetic-attraction relays, 23 of induction relays, 33, 39, 46

Time constant of d-c component, 279

Torque control, see Directional control

Torque production in induction relays, 26

Tower-footing resistance, 303

Transferred tripping, see Remote tripping

Transformer-drop compensation, for directional-comparison pilot relaying, 386

for distance relaying, 352

Transformer protection, see: Electric arcfurnace-transformer protection; Grounding-transformer protection; Power-rectifiertransformer protection; Powertransformer and autotransformer protection; Regulating-trans former protection; Step-voltage protection

Transients, effect of, on directional pilot relaying, 392

on distance relaying, 350

on electromagnetic-attraction relays, 23

on overcurrent relays, 308, 317, 318

Transient blocking, 392

Transient shunt, for distance relays, 351

for overcurrent relays, 310

Transmission-line protection, with distance relaying, 340

with overcurrent relaying, 296

Tranemission-line protection, with pilot relaying, 373

Trap, line, 100

Tripping pilot, 88, 90

Tripping suppressor for transformer differential relays, 256

Tripping, undesired, vs. failure to trip, 11

Undercurrent and under voltage relays, pickup or reset, 45 time, 46

Universal relay torque equation, 39

Variable restraint for generator differential relays, 203

Vector conventions, 53

Vibration, of electromagnetic-attrao relays, 23 protection for generators, 210, 225

Voltage-balance relays, 61

Voltage compensation for ground distance relays, 360

Voltage-regulator protection, 268 see also Regulating-transformer protection; Stepvoltage-regulator protection

Voltage switching for distance relays, 368

Voltage transformers, see Capacitance potential devices; Potential transformers

Watthour-meter structure, 30

Wire-pilot relaying, see Pilot relaying, a-c wire-; Pilot relaying, d-c wire

Zero-phase-sequence-current shunt, currenttransformer connections, 130 used with transformer differential relays, 249