

Bibliography

1. Kloeffer RC, Kerchner RM, Brenneman JL (1949) Direct current machinery. McMillan, New York
2. Kimbark EW (1956) Power system stability. Synchronous machines, vol III. Wiley, New York
3. White DC, Woodson HH (1959) Electromechanical energy conversion. Wiley, New York
4. Shortley GH, Williams DE (1961) Elements of physics. Prentice-Hall, Englewood Cliffs
5. Edwards JD (1973) Electrical machines: introduction to principles and characteristics. Intertext Books International Textbook Company Limited, Aylesbury
6. Slemon GR, Straughen A (1980) Electrical machines. Addison Wesley, Reading
7. Petrović M (1987) Ispitivanje električnih mašina. Naučna knjiga, Beograd
8. Vukosavić SN (2007) Digital control of electrical drives. Springer, New York
9. Wildi T (2006) Electrical machines, drives and power systems. Pearson Prentice Hall, Upper Saddle River
10. Seeley S (1958) Electromechanical energy conversion. McGraw-Hill, New York
11. Brown D, Hamilton EP (1984) Electromechanical energy conversion. McMillan, New York
12. Fitzgerald AE, Kingsley C (1961) Electrical machinery. McGraw-Hill, New York
13. Alger PL (1965) Induction machines. Gordon and Breach, New York
14. Chalmers BJ (1988) Electric motor handbook. Butterworth, London
15. Krause PC, Wasynczuk O, Sudhoff S (1995) Analysis of electric machinery. IEEE Press, Piscataway

Index

A

AC. *See* Alternating current (AC)
Acceleration, 12, 21, 122, 305, 318, 322, 462, 514, 515, 579, 621, 623, 632
AC machines. *See* Alternating current (AC) machines
Active power, 445, 571, 576, 577, 580, 581, 586, 587, 590
Actuator, 413, 621, 631
Air gap, 18, 48, 59, 81, 109, 131, 153–183, 224, 271, 302, 367, 379, 428, 478, 523, 545, 571, 596, 622
Air gap field, 84, 173, 185, 251, 627
Air gap flux, 376, 428, 433, 435, 452, 503, 510, 526, 568, 571, 630
Air gap power, 379, 429–431, 438–441, 446, 468, 470, 471, 473, 478, 481, 492, 545, 622
Alternating current (AC), 1–3, 7, 9, 19, 20, 71, 96, 102, 104, 129, 134, 135, 139, 142, 145–152, 186, 187, 191, 193, 194, 206, 209, 210, 213, 215, 224, 229, 235, 243, 260, 265, 266, 269, 270, 273, 277, 292, 322, 325, 326, 333–335, 338, 340, 341, 345, 369, 371, 373, 376, 380, 382, 386, 414, 419, 432, 469, 476, 477, 481, 482, 494, 498, 499, 501, 521, 522, 524, 535, 536, 555, 572, 576, 585, 586, 591, 607, 610, 616, 624, 628
Alternating current (AC) machines, 18, 19, 88, 121, 141–142, 145, 149, 151, 213, 230, 260, 265, 345, 355, 363, 371, 387, 449, 483, 521, 603
Ampere law, 20, 49, 60–62, 66, 69
Anisotropic machines, 562, 565, 566, 571, 577, 578, 581–584, 633
Anisotropic rotor, 565–567

Apparent power, 431, 443, 445, 577, 580, 581
Armature current, 286, 287, 291, 293–295, 298–300, 303, 308–312, 315–317, 319, 321, 323, 325, 327, 328, 330, 333–339, 345, 346, 348–351, 353, 355, 357, 358, 629
Armature reaction, 281, 283, 286–290, 303
Armature voltage, 308–312, 315–319, 322–326, 330–336, 338, 352, 449
Armature winding, 287, 290–295, 298–300, 302–305, 307–313, 316, 319–323, 325, 326, 329, 330, 332, 334–336, 338, 340, 341, 349, 352, 358–360, 363, 449, 503
Asynchronous machines, 6, 23, 88, 210, 521, 522
Auxiliary poles, 284–291, 303, 358
Auxiliary power supplies, 340
Average torque, 133, 139
Average voltage, 102, 331–333, 339, 496–498, 621, 622
Axial component of magnetic field, 159, 161
Axial component of the rotor field, 177

B

Back electromotive force, 55–57, 61
Balance of power, 90, 120, 122, 124–125, 430, 472–473, 563
Balance of power of induction machine, 537
Base impedance, 443, 444
Base speed, 445
Base torque, 446
Base value, 442–449
Basic frequency component, 242, 333
Belt distribution factor, 232
Belt factor, 223, 232, 236–238, 240, 241, 486

- Bipolar junction transistors (BJT), 326–330, 477
 Block diagram, 6, 125, 306–309
 Block transformer, 9, 605
 Blondel transform, 423
 Blower, 317, 318, 634
 Bobbin, 33
 Braking device, 341
 Braking energy, 341, 624
 Braking unit, 624
 Breakdown frequency, 463
 Breakdown slip, 427, 463–465, 478, 479, 492, 502
 Breakdown torque, 427, 463–467, 479, 492, 502, 506, 511–514, 518
 Breakdown voltage, 344
 Brushes, 210, 264–266, 268–276, 278–284, 286–288, 291–294, 297, 303, 310, 311, 316, 319, 321, 327, 333, 369, 370, 479, 480, 482, 522, 533, 534
 Buried magnets, 522, 537, 541–544, 621
- C**
- Cage rotor, 368–370, 373, 400–403, 405, 408, 409, 418, 419, 427, 430, 431, 433–436, 452, 456, 469, 515, 516, 529, 530, 604
 Cartesian coordinate system, 13, 26, 387
 Cascades, 482
 Characteristic of magnetization, 63, 64, 95, 105
 Characteristic polynomial, 597, 598, 602, 603
 Chord factor, 223, 232–237, 486
 Circular arcing, 280
 Clarke transform, 19, 387–389, 391–398, 400, 428, 429, 432, 439, 448, 550–553, 574, 629
 Coefficient of Clarke transform, 424, 438
 Coefficient of efficiency, 90, 91, 100, 103, 427, 431, 446, 472, 473, 515
 Coefficient of electromagnetic torque, 298
 Coefficient of electromotive force, 298
 Coefficient of inductive coupling, 71
 Coil, 18, 32, 33, 56, 57, 59, 86, 87, 89, 94, 95, 101, 104, 109, 113, 231, 303, 368, 370, 372, 373, 401, 538, 580, 590, 607
 Cold rolled sheets, 531
 Collector, 210, 264–268, 270, 272, 274, 276, 280, 284, 303, 316, 329, 340, 369
 Collector segments, 264, 266–268, 272, 274, 275, 278–280, 283, 286, 292, 294
 Commutation, 260, 270–273, 278–284, 286, 289, 292, 326, 327, 490, 622, 628
 Commutation frequency, 328, 338, 496–499, 543, 628
 Commutation losses, 326, 327, 331
 Commutation period, 496, 622, 627
 Commutator, 151, 210, 260, 261, 263, 266, 269, 272–273, 282, 284, 303
 Commutator segments, 264, 282
 Compensation winding, 285, 286, 288–291, 358
 Complex notation, 13, 420, 421, 425, 558, 573, 576
 Compound winding, 241–242
 Concentrated winding, 88, 154, 173–175, 200, 203, 214, 216, 230, 240, 255, 256, 436
 Conduction losses, 326
 Conductor line density, 201, 205
 Constant flux region, 353, 356, 357, 476, 509
 Constant power region, 509
 Constant torque region, 509
 Construction of induction machines, 365, 513–519
 Contactless excitation system, 535
 Control algorithm, 309, 411, 413, 414, 571, 629
 Controller, 14–16, 308, 309, 413, 491, 506, 586, 610, 625, 628, 629
 Control variables, 307–309, 413, 629
 Convention of representing magnetic field by vector, 182–183
 Conversion cycle, 46–48, 94, 96
 Conversion losses, 6, 17–19, 53, 54, 89–91, 99, 343, 346, 353, 450, 493
 Conversion power, 3, 116, 118, 139, 177, 209, 555
 Coordinate transform, 379, 387, 390, 391, 398, 415, 439, 545, 551, 552
 Copper losses, 91, 212, 306, 358, 359, 429, 430, 443, 446, 450, 451, 463, 469, 470, 472, 514, 529, 537, 538, 563, 564, 568, 582, 598, 634
 Copper losses in stator windings, 469, 581
 Core flux, 59, 61, 66, 67, 70
 Counter electromotive force, 55, 57, 77, 107, 223, 225, 226, 228, 254, 456
 Coupling, 2, 25, 41–57, 65, 81, 99, 133, 177, 188, 300, 357, 400, 442, 535, 563, 590, 596
 Coupling field, 25, 33, 36, 39, 41–57, 94–97, 99, 112–116, 124, 564
 Critical speed, 510–513
 Cross saturation, 300, 408
 CRPWM. *See* Current regulated pulse width modulated inverters (CRPWM)
 Curie temperature, 246

- Current regulated pulse width modulated
inverters (CRPWM), 529
- Current regulator, 529, 624
- Current ripple, 335–339, 499–502, 518, 536,
543
- Cylindrical machine, 18, 81, 83, 119, 153,
155, 161, 162, 168, 177, 181, 188,
201, 530
- D**
- Damped LC circuit, 600–602
- Damped oscillations, 600, 601
- Damper winding, 545, 595, 603–607, 609, 611,
613–615, 617–619
- Darlington, 329
- DC bus, 494, 495, 497, 501
- DC generator, 9, 36, 259, 260, 299, 319–321,
323, 610
- DC link, 340, 341, 494, 496, 499, 624, 626
- DC link circuit, 341, 494, 495, 624, 626, 629
- DC machine power supply, 321–342
- DC machines. *See* Direct current (DC)
machines
- DC machine with permanent magnets, 262, 306
- Declared values, 362, 363
- Deep slot, 518
- Defluxing, 630, 631
- Delta connection, 371, 383, 524
- Demagnetization, 633, 634
- Demagnetizing current, 633
- Density of the field energy, 44, 48, 188
- Diametrically positioned conductors, 155, 230,
232, 237, 400, 484
- Dielectric materials, 33–35, 37, 42, 44, 45,
47, 344
- Dielectric strength, 47, 48, 102, 344
- Differential equation describing changes of
angular speed, 301
- Differential equations of voltage equilibrium,
381
- Differential permeability of permanent
magnets, 542, 566
- Differentiation operator, 307
- Diode rectifier, 2, 326, 327, 331, 340, 477, 481,
482, 494, 535, 536, 624
- Direct axis, 288, 289, 299, 306, 566, 573
- Direct current (DC) machines, 9, 88, 121, 129,
209, 259–364, 369, 449, 483, 629
- Distributed winding, 18, 173–175, 186, 191,
201–203, 205, 206, 223, 224, 230–232,
236, 242, 244–251, 498
- Distribution networks, 3, 340, 580, 581, 605
- Double cage (rotor), 515, 516
- Double cage induction machines, 515, 516
- Double fed machines, 129, 130, 135, 138,
139, 141
- Double side supplied converters, 129
- Driving torque, 5, 11, 124, 273, 317, 321, 322,
586, 592, 600
- Driving turbine, 117, 120, 321, 546, 586, 587
- Dynamic braking device, 341
- Dynamic electromotive force, 223, 224, 242
- Dynamic model, 16, 99, 100, 260, 305, 380,
381, 390, 427, 546
- E**
- Eddy currents, 59, 71–79, 89, 105, 121,
285, 360–362, 367, 430, 469, 488,
531, 604
- Electrical access, 4, 5, 83, 87, 99, 114, 124,
379, 533
- Electrical and mechanical time constants, 596
- Electrical energy, 1–10, 21, 22, 25, 27, 30,
31, 36, 43, 44, 51–55, 82, 83, 90, 97,
116, 117, 259, 294, 319, 321, 322,
325, 326, 340, 341, 370, 468, 472,
473, 475, 546, 563, 574, 586, 588,
592, 605, 634
- Electrical generator, 1–3, 5–7, 18, 67, 83, 605
- Electrical insulation, 75, 76, 78, 89, 344, 346,
362, 367, 369, 451, 504, 533
- Electrical motors, 1–3, 5, 9, 10, 12, 16, 18,
20–22, 91, 124, 308, 321, 322, 330, 331,
357, 413, 580, 622
- Electrical subsystem, 100, 108, 117, 124, 423,
425, 546, 593, 595, 596
- Electrical subsystem of induction machines,
380, 400, 403, 404, 424
- Electrical subsystem of isotropic machines,
561–562
- Electrical vehicle propulsion, 634
- Electromagnet, 59, 522
- Electromagnetic excitation, 261, 532, 533, 565
- Electromagnetic force, 2, 3, 7, 25, 26, 28,
30–32, 39, 51–54, 81, 82, 119, 143, 263,
287, 288, 470, 527, 564, 583
- Electromagnetic torque, 6, 55, 81, 99, 133, 153,
185, 243, 261, 300, 344, 366, 381, 428,
478, 521, 545, 571, 595, 623
- Electromagnetic torque at high slip, 462
- Electromagnetic torque at low slip, 461
- Electromechanical conversion, 3, 4, 18, 22, 25,
33, 38, 39, 41, 46, 47, 49, 50, 52, 53, 59,
60, 83, 90, 94, 99, 103, 112, 114–117,

- 125, 127, 133, 177, 185, 211, 310, 317,
324, 325, 359, 361, 407, 469, 487, 522,
563, 564, 575, 583, 586
- Electromotive force, 2, 27, 52, 61, 88, 99, 154,
223, 261, 304, 351, 366, 385, 433, 489,
521, 546, 573, 605, 627
- Electromotive force in a winding, 230–241
- Electromotive force in distributed winding,
244–251
- Electromotive force in one turn, 224–230, 233,
236, 241, 255, 389
- Electromotive force of compound winding,
241–242
- Electromotive force of self induction, 224
- Electromotive forces induced in the windings,
70, 107
- Electromotive force waveform, 175, 228–229,
250
- Electrostatic field, 29, 33, 35, 41–50
- Electrostatic machine, 18, 33, 41, 44, 48, 50
- End effects, 161
- Energy efficiency, 21, 22, 331, 369, 451, 622
- Energy of electrical field, 35, 301, 381, 424
- Energy of magnetic field, 68, 69, 118, 138, 191,
301, 549
- Energy of the coupling field, 36, 48, 95–97, 99,
112–115, 124
- Equations of mathematical model, 126–127
- Equivalent circuit, 15–17, 19, 260, 261, 299,
301, 304, 309, 312, 319, 336, 387, 411,
412, 427, 432, 434–439, 445, 447–458,
462, 465, 471–473, 480, 502, 503, 546,
573–576, 578, 588, 612
- Equivalent leakage inductance, 453, 454,
464, 617
- Equivalent magnetic pressure, 519
- Equivalent pressure, 35, 519
- Equivalent two phase machine, 385, 388, 390,
395, 396, 411, 548, 552
- Excitation flux, 88, 261, 262, 285–288, 290,
291, 294–306, 308, 310, 311, 318, 321,
323, 351–353, 355, 357, 358, 360, 503,
532, 533, 546, 555, 564, 565, 568, 572,
573, 577, 580, 583, 591, 610, 612, 614
- Excitation winding, 7, 59, 88, 261, 299, 344,
503, 521, 546, 591, 595, 622
- Expression for electromagnetic torque, 126,
211, 301, 441
- Expression for the torque, 21, 207, 208, 212,
381, 425, 442, 546
- External field, 51, 54, 57, 63, 64, 262, 538–540
- External resistor, 294, 370, 479–481
- F**
- Faraday law, 3, 20, 50
- Ferromagnetic, 2, 25, 48, 59, 81, 104, 131,
154, 200, 296, 300, 346, 381, 450,
487, 531, 546
- Ferrite, 76, 488, 538
- Field energy, 35–37, 41–45, 47, 48, 81, 93–97,
113, 114, 118, 133, 138, 185, 188, 189,
191, 194, 422, 428, 431, 549
- Field weakening, 19, 261, 343, 352–357, 476,
504–511, 532, 537, 544, 568, 621,
629–631, 634
- Field weakening region, 353, 357, 506,
508–510, 544, 630
- Finite zeros, 597
- Flux base value, 444
- Flux conservation law, 61–62, 69, 485, 541
- Flux density, 25–29, 32, 38, 74, 213,
450, 490
- Flux in one rotor turn, 198–200
- Flux in one stator turn, 196–198, 526
- Flux in one turn, 110, 175, 182, 194–198,
200–203, 205, 214–217, 225–226,
246–248, 297, 374, 405, 435, 526
- Flux in single turn, 132, 194
- Flux linkage, 3, 20, 185, 223, 300, 301, 379,
390, 399, 404, 409, 415, 417, 419, 420,
425, 427, 433, 436, 438, 445, 448, 449,
526, 545, 546, 549, 553, 555, 557, 559,
561, 562, 566, 574, 576, 593, 595, 596,
608, 610, 615, 616
- Flux of permanent magnets, 572, 581, 623,
627, 630
- Flux per turn, 18, 61, 145, 552
- Flux vector, 18, 28, 63, 108, 143, 170,
185, 262, 372, 383, 444, 522, 549,
575, 624
- Force, 2, 25, 41, 59, 81, 99, 132, 153, 187, 223,
261, 301, 351, 366, 380, 433, 484, 521,
546, 573, 600, 623
- Four pole machines, 141, 142, 490, 492, 529
- Four quadrant operation, 318
- Four quadrant power converter, 325–330
- Fractional pitch coil, 231
- Fractional pitch turn, 231, 233–236, 241,
244, 278
- Free wheeling diodes, 329–330
- Friction torque, 120, 123, 305, 308, 311, 470
- Full pitch coil, 231
- Fundamental frequency component, 498
- Fundamental harmonic, 233, 236, 241, 246,
249, 251, 253

G

- Generalized Ampere law, 49, 66
- Generator mode, 6, 30–31, 53, 55, 83, 90, 116, 117, 123, 124, 311, 317, 319, 321, 323–325, 341, 409, 427, 463, 465, 466, 468, 472, 473, 479, 587, 592, 600
- Good model, 17, 100, 101, 103
- Grooves, 86, 153, 229, 230, 237

H

- Halted rotating field, 147
- Harmonics suppression, 238–241
- Harmonics suppression of winding belt, 238–241
- Heaviside function, 597
- High speed operation, 353–354, 356
- High voltage transmission network, 585, 605
- Homogeneous field, 102
- Hopkins law, 67
- Hot rolled sheets, 531
- Household appliance, 634
- Hunting of synchronous machines, 596–600
- HVAC systems, 634
- Hydro-electric power plants, 534
- Hyperbola of constant power, 356, 357
- Hysteresis curve, 71, 72
- Hysteresis losses, 59, 71–72, 75, 89, 488, 531

I

- Ideal switch, 326
- IGBT. *See* Insulated gate bipolar transistors (IGBT)
- Impedance invariance, 392
- Impedance invariant transform, 551
- Inadequate commutation, 280
- Inductance invariance, 392, 411
- Inductance matrix, 109, 114–118, 126, 127, 132, 137, 138, 301, 379, 381, 383, 400, 404, 407–410, 418, 419, 421–425, 546, 553–554, 556–558, 561, 615
- Inductance matrix in dq frame, 421–423, 556–558
- Inductance matrix of induction machines, 404, 407–410, 418, 424, 425
- Inductance matrix of synchronous machines, 546, 554, 561, 614
- Induct current, 287
- Induction machines, 129, 130, 142, 147, 148, 151, 152, 365–377, 380–425, 427–473, 475–519, 521, 522, 526, 529, 530, 537, 538, 554, 583, 604, 622, 631, 634

Inductor induct, 287

- Industrial robots, 9, 16, 21, 331, 413, 476, 546, 586, 621, 631
- Inertial torque, 305, 314, 602
- Insulated gate bipolar transistors (IGBT), 326–330, 340, 477
- Insulation lifetime, 344
- Interaction of the stator and rotor fields, 185–188, 529, 563
- Intermediate circuit, 624, 629
- Intermediate DC circuit, 340, 341, 494
- Intermittent load, 349
- Intermittent mode, 349
- Internal mechanical power, 90, 91, 470–473, 564
- Invariance, 391–398, 411
- Inverter, 1, 2, 265, 476, 477, 482, 483, 488, 492, 500, 501, 506, 529, 624, 626, 628, 633
- Inverter arms, 494
- Inverter supplied synchronous machines, 621–622
- Iron core, 60, 66, 88, 119, 132
- Iron losses, 59, 75–76, 91, 100, 103–105, 121, 124, 126, 155, 285, 350, 353, 355, 358–362, 367, 381, 410, 424, 429, 430, 438, 446, 450, 469, 470, 472, 488, 531, 536, 537, 546, 563
- Iron losses in rotor magnetic circuit, 431, 469, 470
- Iron losses in stator magnetic circuit, 431, 469, 582
- Isotropic rotor, 136, 561, 562
- Isotropic synchronous machine, 563, 572, 576, 578, 590, 630

J

- Joule effect, 52, 55, 116, 124, 317, 331, 345, 349, 359
- Joule losses, 52, 78, 345, 351, 358, 431, 479

K

- Kinetic energy, 120–122, 125, 341, 362, 588
- Kirchhoff law, 3, 20
- Kloss formula, 465–466

L

- Laminated ferromagnetics, 76–79
- Lamination, 75, 79, 89, 103, 285, 531
- Laplace operator, 307, 597, 602
- Laplace transform, 20, 306, 307, 334, 412, 500, 597, 601

- Lap winding, 278
- Leakage flux, 61, 70, 71, 86, 109–112, 177, 404–407, 452, 454–456, 493, 499, 514, 516–518, 528, 533, 564
- Leakage flux in rotor winding, 112, 405
- Leakage flux in stator winding, 112, 499
- Leakage inductance, 18, 111, 112, 393, 394, 404–407, 409, 433, 434, 447, 451–456, 458, 463, 464, 486, 499, 501, 510, 514, 516–518, 611, 614, 616, 617
- Leakage inductance of stator windings, 434, 611
- Linear commutation, 286
- Linear converter, 50–53
- Linear electrical machines, 10
- Linear motors, 4
- Line density of conductors, 155, 157, 173, 201, 250, 251, 526
- Line frequency, 10, 21, 22, 38, 75, 142, 326, 340, 369, 370, 386, 430, 431, 435, 436, 455, 462, 481, 482, 487, 513, 515, 516, 585–590, 592
- Load characteristics, 313, 314, 317, 319, 480
- Load torque, 5, 11, 12, 19, 300, 305, 310–314, 317, 321, 349, 451, 462, 463, 466–468, 480, 579, 592, 593, 597–600, 603, 623, 631
- Locked rotor test, 455
- Lorentz law, 3, 20, 25
- Losses due to rotation, 99, 125, 358, 361, 427, 469–472
- Losses in armature winding, 359
- Losses in excitation winding, 351, 359
- Losses in magnetic circuit, 71–79, 89, 103, 121, 301, 358, 450, 469, 531
- Losses in mechanical subsystem, 120–121, 469
- Losses in rotor cage winding, 469
- Losses in the coupling field, 99, 115
- Loss power density, 71
- Low-pass nature of electrical machines, 334–335
- Lumped parameter, 101, 104
- Lumped parameter networks, 103, 104, 301
- M**
- Magnetic circuits, 2, 28, 48, 59–79, 81, 99, 129, 153, 185, 224, 261, 300, 343, 365, 389, 427, 483, 521, 552, 582, 596, 622
- Magnetic coupling field, 3, 4, 18, 39, 41–57, 81, 93, 94, 100, 103–106, 113, 116, 117, 124, 126, 133, 136, 137, 188, 563
- Magnetic dipoles, 64, 71, 72, 538–540
- Magnetic field, 2, 25, 41, 59, 81, 104, 129, 153–183, 185, 224, 273, 301, 359, 365, 405, 428, 475, 521, 549, 572, 605, 627
- Magnetic forces, 13, 30
- Magnetic permeability, 62, 188, 452
- Magnetic poles, 23, 51, 85, 141, 170, 187, 232, 262, 361, 411, 440, 475, 524, 553
- Magnetic poles of induction machines, 148, 371, 483
- Magnetic resistance, 18, 20, 28, 31–33, 59, 65–69, 78, 79, 84, 87, 109, 111, 119, 131, 132, 136, 149, 150, 172, 177, 204, 214, 215, 217, 281, 283, 285, 286, 297, 300, 302, 303, 306, 334, 373, 404, 406, 407, 409, 435, 452, 454, 455, 487, 514, 522, 526, 531, 533, 537, 540, 541, 543, 544, 561, 562, 564–567, 583, 616, 623
- Magnetic saturation, 95–97, 126, 211–213, 300, 381, 404, 408, 410, 424, 454
- Magnetic voltage, 20, 67
- Magnetic voltage drop, 215, 285
- Magnetizing branch, 436
- Magnetizing branch voltage, 448, 462, 503
- Magnetizing characteristic of permanent magnet, 538
- Magnetizing current, 433, 435, 438, 439, 447, 448, 451, 453, 456, 457, 465, 503, 504, 509
- Magnetizing flux, 433, 447, 448, 456
- Magnetizing inductance, 451–452, 457, 458
- Magnetomotive force, 3, 65, 81, 113, 132, 153, 190, 242, 261, 301, 372, 380, 435, 484, 521, 547–548, 633
- Magnetostriction, 38–39
- Mains supplied machines, 436, 476–477, 483, 487, 506, 513–517
- Making the rotor windings, 269, 274–278, 532
- Mathematical model, 14–19, 99, 100, 126–127, 261, 299, 300, 305–306, 309, 365, 379, 381, 383, 388, 391–393, 398, 410–411, 413, 414, 419, 423, 424, 431, 438, 452, 455, 521, 545–569, 571, 607, 619
- Mathematical model in stationary coordinate frame, 19
- Maxwell equation, 49, 50, 104, 166
- Mechanical characteristic, 15–17, 19, 99, 100, 260, 261, 291, 299, 311–319, 343–345, 380, 427, 457–464, 466, 476–480, 502, 503, 506, 507, 584–585
- Mechanical characteristic of induction machine, 427, 463

- Mechanical characteristic of synchronous machine, 546
- Mechanical commutator, 260, 263–266, 269, 272–274, 277, 292, 293, 303, 357, 369, 483
- Mechanical interaction, 7, 11, 93, 153, 187, 191
- Mechanical losses, 89, 90, 116, 121, 360, 430, 451, 469–470, 537
- Mechanical losses due to rotation, 99, 358, 427, 469
- Mechanical power, 6, 7, 10, 18, 21, 26–28, 31, 32, 49, 50, 52–54, 83, 90, 91, 99, 116, 117, 120, 122, 124, 319, 321, 322, 356, 359, 361–362, 427, 429–431, 471–473, 478, 481, 564, 568, 583, 585, 588, 589, 591
- Mechanical subsystem, 18, 81, 89, 94, 100, 116, 119–126, 304, 360, 380, 381, 430, 469–471, 473, 545, 546, 557, 564, 592, 593, 595, 596, 599, 622
- Mechanical work, 1–7, 10, 25–28, 30, 31, 33, 35, 36, 38, 41, 43–45, 47, 48, 50–52, 55, 94, 96, 112, 116–118, 123, 218, 259, 319, 321, 322, 341, 473, 475, 546, 563, 586, 592
- Metal oxide field effect transistors (MOSFET), 326–330, 477
- Microscopic Ampere current, 63
- Model of mechanical subsystem, 122–124
- Modulation index, 337, 338
- Moment of inertia, 12, 121
- MOSFET. *See* Metal oxide field effect transistors (MOSFET)
- Motion control, 16, 38, 308, 331, 369, 475, 476, 529, 544, 546, 585, 586, 621–623, 631–633
- Motion cycle, 318, 322, 323, 325
- Motion resistance losses, 121, 124
- Motor mode, 6, 82, 83, 90, 116, 117, 123, 317, 323–325, 465, 466
- Multiple pole pairs, 361, 440, 460, 475, 488, 547, 557
- Multipole machines, 141, 440, 486–490, 492, 572
- Mutual flux, 109–111, 136, 374, 375, 404–407, 435, 436, 452, 472, 499, 503, 526, 533, 535, 610, 616
- Mutual inductance, 18, 108–119, 126, 127, 129, 130, 135, 137–138, 141, 202, 299, 300, 373, 383, 393, 394, 399, 404, 406–408, 418, 421–423, 442, 454, 548, 549, 554, 556, 557, 562, 610, 611, 615–618
- N**
- Nameplate data, 363–364
- Name plate values, 19
- Natural characteristic, 345, 584
- Neglected phenomena, 99, 103–106
- Neutral zone, 272, 280–286, 288–290, 292, 297, 303
- Newton differential equation, 16, 127, 381, 545
- Newton differential equation of motion, 126, 379, 380, 546, 595
- Newton equation, 12, 123, 126, 301, 311, 314, 381, 410, 429, 466, 546, 593, 600
- Newton equation of motion, 429, 466, 546, 561, 586, 588, 623
- Newton law, 83
- No load conditions, 291, 294, 349, 433, 593
- No load speed, 311, 312, 315–317, 502, 633
- No load test, 451
- Nonlinearity of magnetic circuit, 300, 301
- Non-stationary matrix, 126, 554
- Normalized value, 442
- North magnetic pole, 141, 142, 170, 172, 176, 182, 187, 232, 262, 263, 266, 268–270, 275–277, 281, 282, 285, 292, 293, 373, 485–487, 490, 529
- North pole, 142, 169, 173, 183, 263–265, 269, 273, 276, 285, 287, 293, 294, 297, 411, 484, 487
- Number of poles, 141, 142, 440, 441, 475–477, 483, 486–493, 522, 530, 547, 579, 591
- O**
- Operation of commutator, 272–273
- Oscillatory responses, 598
- Overload operation, 343
- P**
- Parasitic capacitances, 103–105, 301, 381, 424, 546
- Parasitic effects, 17, 101, 130
- Park coordinate transform, 379, 439, 545
- Park rotational transform, 417, 422, 558, 560, 576
- Park transform, 390, 415–416, 418, 420, 421, 423–425, 428, 431, 432, 434, 554–557, 559–561, 571, 574, 629
- Peak current capability, 633
- Peak power capability, 598
- Peak torque capability, 14, 544
- Periodic electrical currents, 264

- Permanent magnet(s), 22, 27, 51, 59, 61, 63, 81, 84, 88, 93, 119, 121, 129, 130, 148, 152, 185, 195, 210, 224–229, 235, 242, 243, 245–246, 251, 256, 261, 262, 299, 306, 346, 356, 360, 483, 521–523, 526, 527, 529, 530, 532, 533, 536–546, 555, 556, 564–566, 568, 569, 572, 573, 575, 581, 622–625, 627, 629–634
- Permanent magnet excitation, 22, 299, 306, 308, 530, 533, 536–538, 568, 573, 622, 632
- Permanent magnets on the rotor, 21, 129, 235, 242, 245, 545, 572, 575, 633
- Permeability, 28, 31, 32, 38, 48, 59, 60, 62, 63, 65, 67–69, 84, 88, 92, 95, 96, 105, 113, 131, 136, 154, 155, 157, 158, 160, 162, 164, 167, 168, 181, 188, 197, 212–214, 283, 287, 452, 531, 540–543, 566
- Permittivity, 33–37, 41, 42, 45, 48
- Phase current, 7, 218, 220, 371, 372, 383, 387, 389, 391, 392, 399, 413, 419, 438–440, 448, 485, 490, 500, 523, 524, 526, 529, 547–552, 554, 555, 571, 609, 613, 624, 626–629
- Phase windings, 7, 86, 149, 185, 230, 365, 382, 428, 479, 521, 548, 573, 596, 626
- Phasor diagram, 233, 237–240, 571, 576, 579, 581, 583, 591, 599
- Phasor diagram of anisotropic machine, 581–582
- Phasor diagram of isotropic machine, 576–581
- Piezoelectric effect, 37–38
- Piston, 101
- Pitch of the turn, 231
- Plate capacitor, 33, 42, 48, 626
- Poles of the transfer function, 597
- Polyphasor, 13
- Position control loop, 633
- Power angle, 571, 577, 579, 580, 582–584, 586, 587, 589–593, 595–600, 602–605
- Power balance, 81, 343, 358–362, 365, 427, 469, 537, 622
- Power electronics devices, 2, 10
- Power invariance, 391, 392, 395, 397, 398
- Power losses, 7, 15, 18, 21, 22, 71, 72, 74, 75, 78, 85, 89–91, 114, 115, 120, 317, 347–349, 358–362, 487, 622
- Power of electrical sources, 30, 105–106
- Power of electromechanical conversion, 3, 49, 114–117, 125, 211, 317, 324, 359, 407, 522, 563, 575, 586
- Power of losses, 52, 71, 90, 121, 124, 125, 243, 348–351, 353, 358, 359, 361, 450, 451, 469–471, 563, 575, 631
- Power of revolving field, 421, 429, 459
- Power of rotating field, 429
- Power of supply, 15, 358–359
- Power of the source, 52, 54, 99, 114
- Power supply requirements, 322–323
- Power switches, 326–327, 329, 331, 340
- Power transformers, 1–3, 9, 14, 22, 38, 224, 260, 434, 451, 531, 534, 605
- Poynting vector, 49, 50
- Primary energy sources, 7
- Prime mover, 7
- Problems of modeling, 101–103
- Problems with commutation, 278–283
- Protection system, 605
- Pulse width modulation (PWM), 102, 299, 330–335, 338, 414, 475, 488, 494–500, 518, 529, 536, 543, 586, 622, 629
- PWM inverter, 495, 496, 500
- Q**
- Quadrature axis, 288–291, 299, 301, 303, 573, 575
- R**
- Radial component of the rotor field, 179–180, 198
- Radial component of the stator field, 169
- Rated current, 343, 345–346, 349, 350, 352, 362–364, 443, 448, 451, 452, 454, 457, 462, 467, 468, 480, 500, 508, 511, 514, 517, 543, 581, 631, 632
- Rated flux, 351–353, 355, 361, 363, 364, 456, 502, 505, 506, 508, 510, 511, 517, 630, 631, 633
- Rated rotor speed, 363, 446, 629
- Rated speed, 343, 352, 353, 355–357, 361, 363, 364, 445, 447, 468, 492, 502, 504–506, 508, 509, 537, 544, 629–634
- Rated torque, 308, 343, 356, 445, 446, 449, 468, 508, 517, 529, 632
- Rated values, 14, 19, 261, 343, 347, 351–353, 355, 356, 362, 443–447, 457, 504, 505, 508–511, 513, 515, 540, 543, 630, 631
- Rated voltage, 343–345, 352, 353, 355, 362–364, 442–444, 448, 451, 454, 456, 457, 502, 504, 505, 512, 517, 580, 581, 585, 586, 629, 630

- Reaction of induct, 283, 287, 288
- Reactive power, 546, 581, 586, 590–591
- Reactive power compensators, 580
- Reference direction of magnetic circuit, 69–71
- Region of constant power, 356
- Region of constant torque, 356
- Regulation, 309, 321, 331, 413, 483, 590, 624
- Regulator, 309, 529, 623, 624, 629
- Relative current, 443
- Relative flux, 445
- Relative inductance, 444
- Relative resistance, 443
- Relative slip, 427, 430, 431, 433, 435–439, 441, 445, 446, 451, 453, 455, 457, 459–463, 467, 473, 492, 513–515, 537, 622
- Relative value, 427, 442–449, 451–455, 457, 461, 492, 501, 509, 512, 513, 537, 543, 619, 631
- Relative value of electromagnetic torque, 445
- Relative value of rated torque, 446
- Relative voltage, 443
- Reluctance, 32, 33, 67, 131, 545, 566–569
- Reluctance motor, 567–569
- Reluctance torque, 583
- Reluctant force, 32–33
- Reluctant machine, 131
- Reluctant torque, 31–32, 545, 566–568, 583
- Remanent induction, 532, 538, 539, 541, 633
- Renewable sources, 634
- Representing magnetic fields by vectors, 169–175, 182–183
- Resistance, 11, 28, 51, 59, 89, 99, 131, 220, 223, 259, 301, 352, 369, 380, 427, 475, 541, 545, 573, 596, 621
- Resistance of the rotor winding, 455
- Resultant magnetomotive force, 204, 215, 220, 221, 373, 374, 435, 524, 526, 548
- Resultant magnetomotive force of three winding system, 374
- Resulting field, 84, 185
- Revolving coordinate frame, 19
- Revolving dq coordinate frame, 19
- Revolving magnetic field, 129, 185, 190, 285, 365, 492, 521, 522, 524, 530, 551, 563
- Rheostat, 331
- RI compensation, 509–510
- Right hand rule, 20, 26, 28, 61, 65, 69, 70, 143, 144, 247, 269
- Ripple, 299, 338, 377, 500, 501, 543
- RLC circuit, 600, 601
- Root mean square, 9, 12, 228, 229, 351
- Root mean square (rms) value, 9, 223–230, 232, 236, 238, 241–243, 253–255, 326, 345, 351, 385, 386, 389, 394, 395, 397, 432, 439, 443, 444, 448, 453, 458–460, 470–472, 513, 549, 552, 553, 572, 574–576, 582, 598, 609, 632
- Rotating field, 147, 149–151, 209, 216, 218, 429, 460, 483, 490, 493, 521
- Rotating machines, 13, 81–82, 96, 116, 145–149, 322
- Rotating magnetic field, 18, 149–153, 193, 206, 213–221, 373–374, 484, 486, 493, 499
- Rotating magnetomotive force, 213
- Rotating transformer, 534–536
- Rotational converter, 2, 53–55, 81, 118
- Rotational power converters, 2
- Rotational transform, 419–421, 560
- Rotation losses, 121, 361
- Rotor current circuits, 82, 269, 284
- Rotor field, 81, 93, 151, 176–180, 185–189, 195, 198, 209, 225, 283, 490, 523, 530, 563, 583
- Rotor flux, 7, 84, 110, 136, 177, 185, 224, 261, 299, 373, 400, 444, 521, 555, 572, 622
- Rotor losses, 22, 427, 431, 471, 480, 537, 538, 631
- Rotor magnetic circuit, 86, 97, 109, 119, 121, 131, 132, 136, 141, 153, 154, 164, 169, 172, 175, 177, 188, 196, 213, 224, 234, 246, 281, 283–285, 294–296, 360–362, 366–369, 373, 377, 400, 407, 430, 431, 469–471, 483, 487, 514, 516–518, 521, 522, 527, 529, 530, 536, 537, 539, 541–544, 561, 565–567, 604, 605
- Rotor magnetic field, 147, 175–182, 187, 195, 209, 246, 283–284, 529
- Rotor slots, 154, 177, 263, 267, 268, 272, 367–369, 406, 453, 455, 479, 516, 518, 521, 538
- Rotor speed, 5, 135, 176, 208, 228, 260, 299, 348, 366, 380, 430, 475, 522, 545, 571, 595, 622
- Rotor windings, 84, 110, 129, 153, 185, 224, 260, 303, 366, 379, 430, 479, 521, 545, 606
- Rotor with excitation windings, 521, 532, 533, 565
- Rotor with permanent magnets, 532

S

- Salient poles, 131, 532, 533, 545, 567, 604
- Saturation limit, 213
- Secondary effects, 17, 101, 104, 300, 489, 509, 598
- Section, 46, 60, 86, 100, 151, 154, 192, 230, 272, 300, 351, 397, 485, 565
- Self cooling, 119, 367
- Self-flux, 57
- Self inductance, 18, 56, 57, 68, 69, 74, 94, 95, 108–113, 115–117, 119, 126, 127, 129–133, 136, 137, 202, 303, 375, 399, 400, 404, 406, 407, 418, 422, 452, 454, 486, 522, 541, 543, 544, 561, 562, 566, 575, 581, 596, 607, 611, 616, 621, 633, 634
- Self inductance of rotor windings, 112, 303
- Self inductance of stator windings, 112, 119, 132, 136, 202, 399, 404, 452, 522
- Semiconductor power switch, 1, 10, 325, 326, 328, 329, 357, 414, 476, 482, 586, 633
- Separately excited DC machines, 262, 299, 343, 344
- Separately excited machines, 262
- Series DC motor, 262
- Series excited DC machines, 262
- Short circuited cage5, 60, 370, 402, 456, 479, 521, 604
- Short circuited cage winding, 365, 428, 604–606
- Short circuit of synchronous machines, 605–618
- Short circuit test, 453–455
- Short circuit transient, 606, 608, 610, 615, 617
- Simplified thermal model, 347
- Single fed machines, 129, 131, 139
- Single phase supplied, 342
- Single side supplied converters, 129
- Sinusoidal current sheet, 157–158
- Sinusoidal distribution of conductors, 153, 173, 175, 205, 236, 245, 248–250, 253, 254, 256
- Sinusoidally distributed current sheet, 153
- Sinusoidally distributed windings, 173, 175, 254
- Sliding brushes, 370
- Slip, 142, 374, 385, 427, 475, 521, 568, 603, 622
- Slip frequency, 142, 151, 366, 367, 376, 377, 414, 431, 435, 455, 461, 469, 470, 475, 476, 493, 511, 515–517, 604
- Slip power, 481, 482
- Slip rings, 370, 479–482, 493, 533, 534, 568
- Slip speed, 366, 373, 376, 419, 430, 436, 440, 478, 482, 490, 492, 511, 530
- Slots, 81, 153, 201, 223, 263, 367, 406, 453, 479, 521
- South magnetic pole, 85, 142, 147, 169, 170, 173, 176, 182, 187, 215, 268–270, 276, 277, 281, 285, 292, 293, 297, 373, 483, 487, 490, 529, 557
- South pole, 85, 141, 142, 172, 183, 192, 263, 265, 266, 269, 271, 276, 283, 287, 292, 295, 297, 411, 440, 483–486
- Space vector, 13
- Spatial filter, 223, 236, 245, 250, 253, 254
- Specific energy, 188
- Specific power, 14, 23, 48, 71, 91, 450, 487, 488, 537, 568, 622, 631, 633
- Specific power losses, 72, 78, 450, 451
- Specific torque, 23, 486, 488, 537, 568, 569, 622
- Spectrum, 498, 499
- Speed control, 15, 586, 621, 631, 633
- Speed regulation, 316–319, 369, 475, 478
- Spherical coordinate system, 387, 388
- Squirrel cage, 130, 366, 368, 370, 479, 480, 482, 483, 490
- Squirrel cage rotor, 369, 427, 604
- Stable equilibrium, 135, 313–315, 466, 467
- Stable equilibrium (of induction machine), 466–467
- Star connection, 244, 370, 371, 523
- Star point, 371, 501, 523, 524, 626
- Startup current, 312, 461, 462, 513–518
- Startup torque, 312, 427, 462, 510, 515–517
- State of equilibrium, 579, 587
- State variables, 17, 127, 308, 381, 387–390, 393, 394, 404, 411, 413–416, 421, 424, 430, 431, 554–557, 571, 595
- Static power converters, 1, 2, 9, 10, 14, 21, 22, 260, 265, 309, 317, 321–323, 325, 326, 330, 339–342, 369, 370, 414, 475, 476, 481, 482, 488, 585, 610, 621, 624, 626
- Stationary coordinate frame, 19, 379, 418, 554, 559
- Stator current circuits, 284, 610, 616
- Stator current vector, 415, 439, 447, 528, 529, 548, 556, 567, 624, 626
- Stator field, 169, 176, 179, 183, 186, 209, 262, 264, 269, 283, 366, 379, 409, 490, 522–525, 527, 529, 530, 536, 563, 566, 604, 622

- Stator flux, 84, 110, 131, 183, 186, 256, 261, 373, 385, 444, 478, 522, 549, 574, 608, 623
- Stator magnetic circuit, 86, 109, 119, 131, 136, 153–155, 160, 162–164, 168, 169, 172, 173, 179, 180, 183, 197, 201, 237, 261, 281, 284, 285, 360, 367, 368, 372, 377, 429, 431, 469, 470, 487, 522, 528, 531, 533, 563, 582
- Stator magnetic poles, 188, 264, 271, 272, 275, 280, 282, 285, 288, 292
- Stator magnetomotive force, 143, 173, 261, 374, 383–385, 394, 409, 415, 416, 490, 522, 525, 527, 528, 547, 549, 555, 557, 633
- Stator resistance, 418, 442–444, 449, 451, 455, 457, 460, 463, 465, 493, 501, 502, 509, 575, 577, 579, 582, 606–608, 612, 616, 627, 628
- Stator slots, 86, 154, 368, 372, 483, 487, 489, 523
- Stator windings, 7, 84, 109, 129, 153, 186, 224, 261, 363, 365, 382, 428, 475, 521, 547, 572, 605, 622
- Steady state, 12, 52, 90, 99, 148, 260, 299, 343, 365, 379, 427–473, 525, 545, 571, 595, 630
- Steady state equivalent circuit, 15, 16, 260, 299, 309–311, 365, 380, 390, 412, 427, 433–435, 437, 441, 448, 449, 457, 479, 546, 554, 574, 576, 578, 586, 593, 607, 619
- Steady state operating area, 19, 260, 261, 357–358, 476, 507, 508, 621, 632–634
- Steady state operating region, 556
- Steady state operation, 17, 100, 299, 309, 311, 312, 343, 365, 379, 427, 431–434, 555, 571–593, 607, 608
- Steady state torque, 439–442, 571, 632
- Steam turbines, 5, 7, 21, 259, 273, 294, 317, 585–587
- Stiffness, 312, 314, 315, 502
- Stiffness of mechanical characteristic, 312, 502
- Stiff network, 585–586, 588, 595, 599, 603–605
- Stray flux, 70
- Structure of mathematical model, 381
- Subtransient inductance, 614, 615, 617
- Subtransient interval, 595, 607, 608, 613–615, 618, 619
- Subtransient reactance, 614, 617, 619
- Subtransient time constant, 617, 618
- Summing electromotive forces of individual conductors, 227
- Suppression of higher harmonics, 253
- Surface mounted magnets, 522, 536, 543, 544, 568, 630, 631
- Sustained oscillations, 598, 602
- Switching frequency, 334, 337, 338, 498–501, 536
- Switching states, 327–328, 330–332, 338, 339, 495, 496
- Symmetrical three phase system, 218, 372
- Synchronous coordinate frame, 414–415, 428, 555
- Synchronous generators, 9, 15, 16, 21, 28, 229, 523, 534, 545, 546, 578, 580, 581, 585–593, 595, 596, 603–606, 619
- Synchronously rotating coordinate frame, 561, 572, 576
- Synchronous machines, 4, 88, 121, 129, 210, 230, 265, 361, 440, 521–545, 571, 621
- Synchronous motor, 21, 218, 536, 537, 544–546, 571, 579, 586, 603, 621–624, 629, 631, 632
- Synchronous reluctance machines, 566–568
- Synchronous servo motors, 529, 540, 631, 633
- Synchronous speed, 6, 142, 366, 373–375, 429, 430, 439–441, 445, 446, 451, 456, 459, 460, 462, 463, 468, 470, 471, 473, 475–477, 480, 482, 483, 486–488, 490–493, 498, 499, 502, 506, 511, 514–516, 521, 522, 524, 527, 572, 575, 578, 579, 583–585, 587, 591–593, 599, 600, 603, 604, 615, 622
- System of three windings, 218–221
- System of two orthogonal windings, 213–218
- System outputs, 308
- T**
- Tangential component of the rotor field, 177–179
- Tangential component of the stator field, 179
- Teeth, 81, 84, 86, 87, 407, 454, 518, 519, 531, 541, 543, 544
- Temperature change, 347–349
- Thermal capacity, 346–350, 355, 633
- Thermal equivalent, 9, 351
- Thermal power plants, 534, 580, 585, 604
- Thermal resistance, 345–348
- Thermal time constant, 348–351
- Three phase inverters, 102, 365, 475–477, 494, 496, 497, 499, 503–505, 507, 529, 536, 586, 621, 622, 624, 626, 629, 633

- Three phase supplied, 342
 - Three phase synchronous machine, 545, 547, 551, 621
 - Three phase system of stator windings, 221
 - Three-phase to two-phase transform, 390, 391, 400, 550
 - Three phase windings, 88, 89, 151, 185, 230, 244, 365, 369–371, 374, 382–385, 388, 392, 397, 399, 402, 432, 435, 439, 479, 484, 490, 521, 523, 524, 526, 530, 548, 549, 551, 552
 - Thyristor, 2, 342, 481, 610
 - Thyristor converters, 342, 481, 482
 - Time constants of electrical subsystem, 593, 596
 - Time constants of mechanical subsystem, 593
 - Topologies of DC machine power supplies, 321–342
 - Topologies of power converters, 339–342, 475
 - Torque actuator, 369, 586, 623
 - Torque change with power angle, 583–584
 - Torque command, 586
 - Torque control, 299, 300, 308–309, 623–626
 - Torque control loop, 300
 - Torque expression, 117–119, 138–140, 185, 193–194, 212, 376–377, 410, 422, 429, 448, 458, 460, 461, 463, 564, 566, 568
 - Torque generation, 32, 152, 185, 208–211, 282, 294–295, 375–376, 489, 503, 509, 518, 521, 522, 527–530
 - Torque in anisotropic machine, 582–583
 - Torque in isotropic machines, 563–564
 - Torque per Ampere ratio, 529
 - Torque-power angle relation, 595
 - Torque reference, 21, 308, 623, 624, 626
 - Torque reference direction, 300
 - Torque size relation, 211–213
 - Total energy accumulated in magnetic field, 189
 - Transfer function, 302, 307, 308, 334, 500, 597, 598, 629
 - Transformer, 9, 22, 63, 71, 75, 223, 224, 343, 380, 427, 434–437, 451, 453, 454, 481, 522, 534, 535, 580, 585, 605, 611, 614
 - Transformer electromotive force, 223, 224
 - Transient analysis, 593
 - Transient characteristics, 343, 357, 358
 - Transient inductance, 618
 - Transient interval, 593, 595, 607, 608, 611–613, 617–619
 - Transient operating area, 19, 507–508, 621, 632
 - Transient operating region, 19
 - Transient reactance, 619
 - Transients in synchronous machines, 595–619
 - Transient state, 578, 596
 - Transient time constant, 595, 612, 618, 619
 - Transistor power switch, 265, 494, 622, 624, 626, 628
 - Transmission networks, 7, 9, 585, 587, 605
 - Turbine power, 117, 321, 587–589
 - Turns, 11, 59, 83, 108, 131, 153, 185, 223, 263, 301, 346, 365, 383, 433, 485, 523, 548, 616, 628
 - Two phase equivalent, 379, 384, 385, 387–399, 402, 403, 405, 408, 411, 424, 434, 548–553, 561
 - Two phase equivalent machine, 385, 388, 390, 395, 396, 411, 548, 552
 - Two pole machines, 23, 141, 142, 148, 373, 421, 440, 460, 476, 483, 486, 488–490, 492, 530, 557, 593, 596
 - Two speed stator winding, 490–492
- U**
- Unfolded form of windings, 274, 278
 - Unstable equilibrium (of induction machine), 466–467
- V**
- Variable frequency supplied machines, 364, 511
 - Variable frequency synchronous machines, 621–634
 - Variable mutual inductance, 130, 135, 554
 - Variation of rotor resistance, 477
 - Variation of self inductance, 132–133, 136
 - Variation of stator voltage, 477
 - Variation of the number of poles, 477, 493
 - Vector product, 20, 26, 29, 49, 52, 85, 142–145, 185, 187, 192, 194, 205–208, 211, 213, 261, 281, 287, 290, 291, 294, 447, 449, 503, 522, 523, 527, 528, 623
 - Vectors as complex numbers, 558–559
 - Vehicle propulsion, 546, 621, 622, 634
 - Virtual disturbances, 43
 - Virtual work, 43–45
 - Voltage balance equation, 16, 57, 107–109, 114, 301–304, 309, 310, 312, 383, 385, 399–400, 412, 417–419, 423–424, 433, 436, 444, 499, 546, 548, 553–554, 557–561, 564, 581, 593, 606, 607, 610, 612, 627, 628

- Voltage balance equations at steady state, 427, 432, 434, 571–573
- Voltage balance equations for rotor windings, 403, 408, 424, 434
- Voltage balance equations for stator windings, 434, 502, 518, 558, 560, 563
- voltage balance equations (of induction machine) in the steady state, 380, 432
- Voltage balance in one turn, 227–228
- Voltage balance in windings, 546

- W**
- Water turbines, 3, 273, 317, 587, 588, 591, 592, 596, 600
- Wave windings, 278
- Well damped response, 603
- Winding, 2, 28, 50, 59, 81, 99, 129, 153, 185, 223, 260, 279, 343, 365, 379, 427, 475, 521, 545, 572, 595, 622
- Winding axis, 88–89, 109, 146, 171, 172, 203, 205
- Winding belt, 231, 237–241, 244
- Winding flux, 18, 59, 63, 65, 69, 106, 108, 112, 139, 149, 153, 171, 173, 182, 185, 194–204, 224, 246, 250, 251, 253, 373, 406, 436, 526, 607, 615
- Winding flux vector, 171, 182, 203–205, 372
- Winding losses, 89, 99, 115, 350, 351, 472
- Winding phases, 150, 491
- Winding resistance, 89, 106, 115, 223, 352, 403, 434, 442, 451, 453, 486, 487
- Wind turbines, 21, 634
- Wiring diagram, 269, 270, 292
- Work machine, 5, 6, 10–12, 14, 15, 32, 81, 82, 90, 96, 101, 117, 120, 122, 123, 304, 305, 310, 313, 314, 317, 318, 322, 360, 361, 430, 451, 466, 546, 586, 603
- Wound rotor, 369, 370, 479–481, 493, 546, 553
- Wound rotor induction machine, 370, 482
- Wound rotor machines, 369, 370, 479–482, 568

- Y**
- Yoke, 284, 285, 287, 407, 487

- Z**
- Zeros of characteristic polynomial, 597, 602