Index

a
Acceleration 52
of BEV using PM dc machine 451
of BEV using WF dc machine 452
time-step estimation 57
AC-DC rectifier 302, 419
AC machine 6, 163
asynchronous 165
delta (mesh) 209
distributed winding 210, 253
magnetic axis 209, 257
pitch
   fractional 211
   full 211
slot 216
space vector 211, 291
spinning magnetic field 163, 207
star (Y, wye) 208
stator magnetic flux density 209
stator winding 207
synchronous 165, 213
synchronous frequency/speed 165, 213
three-phase windings 208
tooth 216
yoke 216
AC Propulsion 7, 416
tzero 7
Advisor 2.0 software 155, 156
Aerodynamic drag 42
AeroVironment 5
AESC 70, 71, 78
After treatment 13, 18
Air Resources Board 15, 16
Alkaline battery 69, 79
Alternating current (ac) 4, 161, 302, 414
Alternator 162, 304
Aluminum 6, 216, 303, 465
Amorphous-metal 471, 472
Ampere 77, 463
Ampere, Andre-Marie 77, 461, 463, 464
Ampere-hour 77
Ampere-Maxwell law 462, 463
Ampere's circuital law 220, 463, 475
Ampere's force law 509
Anheuser Busch 5
Anion 74
Anode 74, 114
Argonne National Laboratory 27
Arrhenius, Svante 82
Aristotle 149
Atkinson cycle 6, 132, 136
Atkinson, John 132
Atomic mass unit 13
Average see Direct-current (dc)
Azure Dynamics Transit Connect
  Electric 67

b
Back emf 162, 180, 218, 474, 475, 500, 512, 513
of a machine coil 249
of a machine phase 250, 253
Base speed 55, 172
Battery 68, 74
  alkaline (see Alkaline)
Battery (cont’d)

beginning of life (BOL) 25, 81
capacity 77
capacity rate (C-rate) 77
cell 69
cell voltage 79
cell voltage 
charge/discharge 81
charge equalization 75
charging 88, 412
cycle life 80
cycle lifetime index (L) 84
deepth of discharge (DOD) 79
discharge curve 80
electrodes 73
electrolyte 73, 74
end of life (EOL) 25, 81
failure 88
float voltage 82
lead-acid (PbA) (see Lead-acid)
life testing 83
lifetime 31, 81
lithium-ion (Li-ion) (see Lithium-ion)
management system (BMS) 89
memory effect 76
nickel-metal hydride (NiMH) (see Nickel-metal hydride)
pack 69, 78
power-to-energy ratio (P/E) 72
primary 69, 74
protection 88
rated voltage 79
secondary 69, 74
self discharge 81
separator 73
sizing 81
sodium sulfur (see Sodium sulfur)
solid state 68
specific energy 72, 80
specific power 72, 81
state of charge (SOC) 79
temperature, cold 83
temperature, high 82
thermal stability 89
time 81, 83
voltage 82

Battery-electric vehicle (BEV) 29, 30, 102
range 24, 49
Battery internal resistance 90

activation polarization 90
concentration polarization 91
ohmic 90
Battery model 90
BEV 92, 108
HEV 96
Battery pack 69
efficiency 95
parallel 69
resistance 95
series 69
series-parallel 69
Benz, Karl 3, 4
BH characteristic 468
Biot and Savart, law of 475
Biot, Jean Baptiste 475
Bipolar junction transistor (BJT) 303
BMW 1 Series Active E 67
BMW i3 67
Bode, Hendrik 441
Boost (step-up) 306, 325
boundary-conduction mode (BCM) 330
capacitor sizing 343
continuous-conduction mode
(CCM) 326
discontinuous-conduction mode
(DCM) 332
inductor sizing 342
interleaved 343
power-factor correction 420, 428
Brake horsepower 281
Brake specific fuel consumption
(BSFC) 134
Matlab 156
Brazing 216
BRG Bluecar 67
Buck (step-down) 306, 307, 355
boundary-conduction mode (BCM) 317
continuous-conduction mode
(CCM) 309
discontinuous-conduction mode
(DCM) 319
Buck-boost (step-down/step-up) 306, 391
BYD E6 67

C

Cadillac 5
California 5, 15
Capacitance 463, 507
Capacitor 506
dc link 419
electrolytic 428, 508
polypropylene 508
sizing of 508
supercapacitor 508
Carbon dioxide (CO\(_2\)) 13
equivalent (CO\(_2\)e) 27
Carbon emissions 12, 25
electrical grid 28
tailpipe 25
total 26
upstream 25
Carbon monoxide 13
Carrier gear 149
Casting 216
Catalytic converter 13, 15, 16
Cathode 74, 114
Cation 74
Center for Evaluation of Clean Energy Technology 86
Charge depleting (CD) 31
Charge sustaining (CS) 31
Charging 88, 412
architectures 414
conductive 414
grid voltage 416
inductive 377, 415, 425
integral 416
requirements 412
sine squared 430
wireless 377, 415, 427
Charging standards 422
CCS Combo 424
Chademo 425
IEC 62196 422
SAE J1772 422
SAE J1773 427
SAE J2954 427
Tesla 425
VDE-AR-E 2623–2 425
Chevy Bolt 8, 67, 71, 72
Chevy Spark 67
Chevy Volt 8, 27, 43, 47, 70, 71, 87, 148, 168
Cicero, Marcus 3
Clarke, Edith 292
Clarke-Park transformation 292
Climbing resistance 51
Coal 10, 11, 28
Coast-down test 46
Cocconi, Alan 7
Coda EV 67
Coercivity (Coercive force) 468, 489
Complex conjugate 259
Compressed natural gas (CNG) 10, 11, 28, 112, 113
Compression ignition (CI) 29, 131, 137 see also Diesel
Continuously-variable transmission (CVT) 6, 33, 53, 131, 148
Control 441
of speed loop 449
of torque loop 448
Conversion factors 176, 519
Copper 216
temperature co-efficient of resistance 202
Copper fill factor 487, 506
Copper loss 484
of helical winding 485
Core loss 471, 482, 484
equivalent parallel resistance 484
Corporate Average Fuel Economy (CAFE) 15, 16
Coulomb 77
Coulomb, Charles Augustin de 77
Cradle-to-grave 27
Current-ripple ratio 314
d DC-AC chopper 422
DC-AC inverter 302, 392
DC-DC power converter 122, 301, 302
DC machine 162, 178
armature 179
armature reaction 192
brushed permanent-magnet 162
constant-torque mode 193
efficiency 186
electromagnetic power 183
electromechanical power 185
EV powertrain 193
maximum power 184
no-load speed 184
power-drop-off mode 194
Index

power electronics 186
power loss 185
temperature rise 202
torque versus speed characteristic 183
brushed wound-field 162
constant-power mode 197
constant-torque mode 196
EV powertrain 195
brushes 180
commutator 180
compound 180
electrical circuit 180
electronically-commutated (trapezoidal-waveform brushless) 163
equations 181
rotor 179
saturation 192
series-wound 180
shunt-wound (parallel) 180
stator 179
de Ferranti, Sebastian 488
Delphi 71
Demagnetization 491
Dendrite 76
Diesel 5, 10, 11, 112, 131, 136
emissions scandal 9, 15, 16
Diesel, Rudolf 5, 132
Differential 138
Diode 336
conduction loss 339
inverse 308
power loss 337
reverse recovery 336, 339
switching loss 339
thermal impedance 341
Direct (d) axis 257, 278, 291
Direct-current (dc) 161, 321, 334, 390, 401, 432
Downgrade force 51
dq modelling 291
constant-current transformation 292
constant-power transformation 294
Drag coefficient 42
Drive cycle 19
EPA 19
FTP 19, 20
HFET 20, 21
JC08 19
LA4 19
New European (NEDC) 17, 19, 25
SC03 19–21
simple 35, 60, 102, 126, 138
UDDS 19
US06 20–21
WLTP 19
Dual-clutch transmission 149
Duty cycle 308, 357, 371
Dynamometer 19, 24, 134, 281
e
Eddy-current loss 471, 483
Edison, Thomas 4, 68, 206
Efficiency map 272, 274
Electric field strength 462, 463
Electric flux 463
Electrochemistry 74, 90
Electrode 114
Electrolyte 74, 114
Electromagnet 497
Electromagnetic interference (EMI) 302, 508
filter 420
Electromagnetism 462
Electromechanical energy conversion 509
Electromobility 3
Energy 41
due to magnetic field 481
Energy density 7, 10
Engine 131 see Atkinson cycle; Compression ignition (CI); Spark-ignition (SI)
efficiency 135
Environment 3
Environmental Protection Agency (EPA) 9, 16, 24, 25, 43, 46
Epicyclic gears 131, 148
Euro 1-VI 18
f
Faraday, Michael 461, 463
Faraday’s constant 90, 116
Faraday’s law of electromagnetic inductions 218, 462, 463, 475, 512
Federal Air Quality Act 16
Federal Communications Commission (FCC) 302
Feedback control 442
FEMM 279, 298, 518
Ferrite 472
magnets 249, 470
Ferromagnetic elements (iron, cobalt, nickel) 470
Ferromagnetism 467
hard 470, 489
soft 470
Fiat 500e 67
Field-weakened mode 197, 236, 266
Fleming left-hand rule 509
Fleming right-hand rule 512
Float voltage 82
Flyback power converter 354, 391, 419
Ford Explorer 45
Ford Focus 67, 87
Ford, Henry 3, 5, 161
Ford Model T 5
Ford Motor Company 354
Forward converter 354, 355
currents 357
transformer area-product 365
voltages 362
Fracking 10, 113
Fuel cell 111
aging 122
alkaline 112
balance of plant 9, 112, 118, 121
beginning of life (BOL) 123
cell voltage 116
current density 116
electric vehicle (FCEV) 9, 29, 33, 112
end of life (EOL) 123
exchange current density 116
lifetime 122
model 116
open-circuit reversible voltage 116
PEM (see Polymer electrolyte membrane (PEM))
polarization curve 119
size 120
solid-oxide 112
specific resistance 116
stack 120
thermal management 116
upstream emissions 128
water management 116
Fuel cell internal resistance 116
activation polarization 116
concentration polarization 117
ohmic 116
Fuel consumption 24
Fuel-to-air ratio 12
Full-bridge power converter 354, 365, 422
currents 370
transformer area-product 376
voltages 373
Fundamental-mode analysis 381
g
Gallium nitride 304
Gas diffusion layer (GDL) 115
Gasoline 10, 11, 113
Gauss, Johann Carl Friedrich 462
Gauss’ law of electricity 462
Gauss’ law of magnetism 462, 463, 466
General Motors 5, 8, 72
General Motors EV1 xix, 6, 9, 16, 43, 71, 206
General Motors Impact 6, 7, 43, 416
General Motors Saturn 137
Gibbs free energy 90, 116
Gibbs, Josiah 90
Goodenough, John 6, 68
Gradability 51
Greenhouse gas (GHG) 13
GREET model 28, 113
Grid voltages, frequencies and wiring 416
Grove, William 112
Grubb, Willard Thomas 112
h
Haagen-Smit, Aries Jan 4, 5, 16
Half-bridge power converter 307, 337, 398
Half-cell reaction 74, 115
Heating, ventilation and air-conditioning (HVAC) 20, 21, 24, 50
Heaviside, Oliver 462
Hertz, Heinrich 462
Hindenburg airship 113
Nickel-metal hydride battery (NiMH) 6, 68, 69, 74, 79
Niedrach, Leonard 112
Nissan Leaf 7, 16, 24, 25, 43, 47, 51, 56, 63, 67, 70, 71, 78, 167
Nissan Leaf battery chemistry 70
Nissan Leaf battery pack 78
Nissan Motor Company 7
Nitrogen dioxide 14
Nitrogen oxide 14
Nitrous oxide 13
No-load speed 184, 265
No-load spinning loss (core, friction and windage loss) 183
Norway 31, 35
NOx 14
Nyquist, Harry 441

O
Oak Ridge National Laboratory 150, 164, 167, 175, 176, 207, 253, 281, 302–304, 468, 491
Otto cycle 132
Otto, Nicolaus 132
Ovonics 71
Oxidation reaction 74, 114
Oxidation-reduction reaction (redox) 74, 114
Ozone 14

P
Panasonic 71
Parallel hybrid electric vehicle 29, 32
Park, Robert 292
Particulate matter 13
Permanent magnet 489
  lifting force 494
  recoil line 491
  relative permeability 491
Permanent-magnet ac machine, interior (IPM) 6, 166, 276
DC torque test 282
  direct (d) axis 278
  efficiency maps 175
  high-speed operation 289
  low-speed operation 286
  magnet (synchronous permanent magnet) torque 276
maximum torque per ampere (MTPA) 289
maximum torque per flux (MTPF) 289
maximum torque per volt (MTPV) 289
no-load spin test 282
  pitch (full) 211
  quadrature (q) axis 278
  reluctance torque (synchronous reluctance) 277
  saliency 278
Permanent-magnet ac machine, surface (SPM) 166, 249
  apparent power 259
  direct (d) axis 257
  efficiency map 272, 274
  equivalent magnetizing current 268
  field-weakening 266
  high-speed operation 266
  leakage inductance 256
  magnetizing inductance 256
  no-load speed 265
  per-phase equivalent circuit 256
  power factor 260
  quadrature (q) axis 257
  reactive power 257
  real power 259
  saturation 263
  self inductance 256
  synchronous inductance 256
  torque-speed characteristic 264
Permeability 465
  absolute 465
  of free space 465
  incremental 470
  relative 465
  relative incremental 470
Permittivity 462, 507
Peroxyacyl nitrates (PANs) 14
Peugeot 5
Planetary gears 148
Platinum 114
Plug-in hybrid electric vehicle (PHEV) 8, 31
Pole (switching) 393
Pollution 5, 13
Polymer electrolyte membrane (PEM) 112, 114
Powder core 472
Power 41, 99, 120, 185, 405, 429
   apparent 241, 259, 419
   reactive 241, 259
   real 222, 241, 259, 287, 419
Power-drop-off mode 266
Power factor 231, 260, 419
Power-factor correction boost 427
   inductor 430
   rectifier 431
   switch and diode currents 432
Power semiconductor 336
   power loss 227
Power-to-energy ratio 72
Powertrain 4, 131
Principia, 40
Proportional-integral (PI) controller 447
Proton exchange membrane (PEM) 112, 114
PSIM 349
PSPICE 349
q
   Quadrature (q) axis 257, 278, 291
r
   Range 24
   Rated/base/nominal speed 55, 172
   Rated conditions 55, 172
   Reaction quotient 90, 116
   Reagan, Ronald 16
   Reduction reaction 74
   Regenerative braking 31, 33, 51, 54
   Regulations 15
   Reluctance 478
   Reluctance machine 166
   Renault 5, 416
   Residual-current circuit breaker (RCCB) 420
   Resonant power converter 377
      series-parallel 377
      characteristics 378
      operation 378
      simulation 385
   Right-hand screw rule 464
   Ring gear 149
   Rippel, Wally 7
   Road-load force 40
Rolling resistance 45
Root-mean-squared 312, 323, 334, 390, 403, 434
Rotor 161
Routh, Edward John 441
s
   Saliency 274
   Savart, Felix 475
   Series hybrid electric vehicle 29, 32, 33, 131
   Series-parallel hybrid electric vehicle 29, 33, 131
   Shockley, William 301
   Silicon carbide 304, 435
   Silicon steel 472, 473
      grain oriented 472
      non-grain oriented 472
   Silicon Valley 7
   Simetrix 349
   Sintering 472
   Skin depth 241, 488
   Slip speed see Induction machine
   Small-signal models 443
      DC-DC power converter 447
      mechanical system 443
      PI controller 447
      PM dc machine 446
   Smog 5
      London-type 5, 16
      Los Angeles-type 5, 16
   Sodium sulfur 89
   Solar Challenge 5
   Space vector 211, 291, 392
   Spark-ignition (SI) 13, 29, 131, 137 see also Gasoline
   Specific energy 11, 135
   Spontaneous process 90
   Starter motor 162
   Stator 161, 207
   Steam reforming 33, 113
   Steinmetz, Charles 464
   Steinmetz coefficients 484
   Sun gear 149
   Sunraycer 5
   Switch-mode power converter 302
   Synchronous frequency/speed 165
   Synchronous rectifier 366
Index

T
Tafel equation 117
Tafel, Julian 117
Temperature rise 176, 202, 240
Tesla Model 3 7
Tesla Model S 7, 43, 46, 47, 66, 67, 69–71, 167, 206
Tesla Model X 7, 22, 23, 27, 67
Tesla Motors (Tesla Inc.) 4, 7, 465
Tesla, Nikola xix, 3, 4, 6, 163, 206, 412, 465
Tesla Roadster 7, 16, 70, 71, 167
Tesla unit 465
Thermodynamics, first law of 10
Thyristor (silicon-controlled rectifier) 303
Tire specification 66
Torque
  general expression 162, 510
  magnet 166
  motive 53
  reluctance 166
  vs. speed characteristic 264
Toyoda, Kiichiro 131
Toyoda, Sakichi 131
Toyota Camry (2007) 164, 167, 207
Toyota Mirai 9, 10, 25, 27, 43, 112, 121, 122
Toyota Motor Company 6, 131, 132, 150
Toyota Prius 2, 6, 148
  1997 6, 16, 70, 71, 134
  2004 149, 150, 167, 207, 253, 279, 280
  2010 150, 302–304
  2015 43, 47
  2017 Eco 21, 27
Toyota RAV4 EV 67
Toyota Scion iQ EV 67
Traction drive 392
Traction machines 161
  comparison 167
  constant-power mode 55, 174
  constant-torque mode 55, 173
  efficiency maps 175
  four-quadrant operation 170
maximum-speed mode 174
peak operation 173
rated parameters 171
stall 173
start-up 173
thermal 201
Transformer 206, 219, 355, 422, 498
  area product 365, 378, 505
  equivalent circuit 206, 207, 500
  leakage inductance 378, 500
  magnetizing inductance 356, 500
  primary 219, 356, 366, 377, 499
  secondary 219, 356, 366, 377, 499
  sinusoidal excitation 503
  squarewave excitation 504
  tertiary 356
  theory 498
  turns ratio 501
U
Upstream emissions 128
Urea 15
US Hybrid xx, 122, 166, 207, 216
V
Vehicle to grid (V2G) 416
Verne, Jules 111
Volkswagen 9, 15, 16
eGolf 67
Volt 73
Volta, Alessandro 73
Voltage 73
Voltaic cell 74
W
Watt 41, 76
Watt-hour 77
Watt, James 41, 441
Well-to-wheel 27
Westinghouse, George 4
Wide band gap semiconductors 304