Index

acceptance characteristics, 173–4
AC impedance, 53
active circuit, 245
active ground detection method, 244–6
active materials, 15
actual available energy, 96–8
actual charging capacity, 133
actual resting voltage, 72
adaptive neuro-fuzzy inference system (ANFIS), 57–60
aging, 47
  of battery, 78–80
  degree, 158
  distortion factor, 155–6
  paths, 79
Ah counting method, 52–4
Ah integration, 36
alarm threshold values, 259
allowable charge current, 174
analog digital converter (ADC), 234, 239, 240
circuit, 232
analog integrated temperature sensor, 237
analysis method, 197–201
anode, 10
anti-abuse ability, 225
anti-abuse capabilities, 4
anti-interference ability, 231
application issues, 3–4
available capacity inconsistency, 120
available power, 117–21
average charging current, 145
average charging time, 143–6
average power, 108
back propagation (BP), 59
balance control, 232
battery, 258
  acceptance interval, 171
  aging, 79
  aging state, 160
  capacity, 221
  charging methods, 129
  consistency, 179–223
  energy ratio, 135
  equalization, 7
  inconsistency, 180–182
  model, 9
pack, 26, 36, 74, 92, 93, 117–21, 194, 204–5, 208–23,
  242, 248, 250, 255
pack modeling, 34–42
pack performance, 182–3
power density, 102–3
state estimation, 7
terminal voltage, 195–7
thermal field distribution, 181
voltage, 234
voltage platform, 189–90
battery control unit (BCU), 227, 268
battery electric vehicles (BEV), 226
battery management system (BMS), 21, 78, 80, 83, 126,
  225–30, 226, 227, 238, 252, 253, 260–274
battery management technology, 4–7
battery measurement unit (BMU), 227, 267, 268
BMS-Cooperation Control Mode, 125–6
BMS design, 7
BMS-dominant control mode, 126–7
breaking down, 262
bypass resistance, 251
cabinet, 114
calculation, 212–16
calculation formula, 150
CAN bus, 252
CANopen, 254
capacitor equalization, 249–50
capacity, 136, 183
coefficient, 165
difference, 40, 187
loss, 137
use, 182
utilization, 201, 222
utilization rate, 203–6, 214, 218
cathode, 10
causes, 180–182
cell voltage measurement, 230–232
centralized equalization converter, 247–9
change rate, 195–6
charging-current mode, 64
charge capacity, 130–135
charge control, 256–8
charge–discharge current, 88, 90
charge–discharge process, 94, 97
charger-alone control mode, 124, 125
charging
Ah efficiency, 136–8
capacity, 125, 131–5, 142, 143, 176
characteristics, 130
conditions, 140
current, 67, 131, 146, 168
and discharging capacity, 90
and discharging process, 89
efficiency, 135–41
equalization capacity, 214
life, 167
methods, 127–9
modes, 123, 124
online technology, 274
peak power, 102, 110
polarization, 150–160
receptivity, 128
stress, 140
technologies, 123–9
temperature, 145
time, 141–6, 167, 176
voltage, 146–7
Wh efficiency, 138–41
charging CAN bus, 253
charging–discharging current ratio, 76–8
chemical balance, 20
chemical reaction, 33
circuit loop, 256
communication data, 254–5
communication protocols, 253
comparisons, 2, 172–7
comprehensive management, 6–7
computing method, 213
confirmation, 214–17
consistency, 196
consistency evaluation, 220, 223
constant-current (CC), 64, 141, 164–5
charging, 132–3
charging method, 127
fast charging, 166
constant current–constant voltage
(CC-CV), 75
charging, 144
method, 163–7, 175, 176
constant polarization charging method(cvp
charging method), 172–7
constant power, 102, 111
method, 109–12
test, 107
constant voltage (CV) charging method, 127
constant voltage point, 165
control object, 218
control strategy, 4, 126, 219–21
control value, 170
corvergence speed, 86
corversion ratio, 137
current
acceptance characteristics, 140
control method, 127
difference, 187
drop, 148
fluctuation, 3
imbalance, 38–40, 117, 183, 189
injection, 246
measurement, 238–41
pulses, 106
rate, linear characteristics, 159
sensor, 239–40
stress, 139
curve fitting, 148
cut-off point, 32
cut-off voltage, 49, 105, 175
CVP method, 173, 175, 176
cycle life electrochemical impedance
spectroscopy (EIS), 16
data communication, 251–5
DC internal resistance, 139
DC internal resistance consistency, 193
DC resistance, 150, 198
deficiencies, 129
definition, 139
degree of aging, 174
depolarization, 63, 64, 66, 71
depolarization capacity, 68, 71
depolarizing time, 65–7
depth of discharge (DOD), 160–163
development, 5–7, 124–7
development goals, 1
dielectric resistance, 260–262
discharge curves, 44
discharge efficiency, 11
discharging peak power, 102
discharging procedures, 49
discrete scheme, 230–232
distortion factor, 153–5
distributed direct current conversion module, 247
divider ratio, 245
ΔQ/ΔV curve, 78, 80
dynamic charging and discharging efficiency, 15
dynamic stress test (DST) cycle, 12–13, 30
EEPROM, 83
effect confirmation, 222
efficiency, 89
electrical equivalent circuit Unbalanced current, 42
electric control units (ECU), 252
electric vehicles (EV), 1, 225
electrochemical impedance spectroscopy (EIS), 17, 53
electrochemical mechanism, 94
electrochemical model, 22–4
electromagnetic interference, 244
electromotive force, 52
electromotive force method, 50–52
emergency charging mode, 266, 267
end of discharge (EOD) voltage, 46
energy, 221
loss, 89
non-dissipative type, 247–50
use, 182
utilization, 6, 201, 222
utilization efficiency, 97
utilization rate, 206–9
equalization, 179–223
capacity, 212–14
charging capacity, 216
criteria, 204
judgment, 210
method, 212
strategy, 210, 211, 215, 218, 221
equalizer, 220
equivalent circuit model
over-charge/overdischarge, 35
equivalent circuit models, 21–2, 24–31, 33
error covariance, 84
error curve, 86
estimation errors, 69
estimation of battery state, 182
evaluation, 179–223
evaluation indexes, 183–201
exponential area, 32
extended Kalman filter (EKF), 54, 55, 80–86
external ADC, 241
external voltage, 77, 198–200, 202, 210, 219–21
fashover, 262
fault detection, 233, 235
fault diagnosis, 263
Federal Urban Driving Schedule (FUDS), 67, 70
filter capacitor, 256
fitting effect, 72
fitting polarizing voltages, 72
fly-back convertor, 248
fuzzy algorithm, 168
fuzzy inference, 57
gain factor, 84–5
Gaussian function, 58
gradient characteristics, 156–60
ground insulation resistance, 244
hall voltage, 239
high-precision, 234
high voltage measurement module, 228
hybrid electric bus, 269–71
hybrid electric vehicles (HEV), 226
hybrid power electric vehicles, 103–4
hybrid pulse power characterization (HPPC), 105–6, 112, 113, 115, 116
test, 25, 26
hysteresis effect, 134
implementation method, 169
improved CCCV method, 165–6
inconsistency, 34, 74, 79, 117, 121
inconsistency influence, 182–3
inflection point, 156–8
influence, 161–3, 198–201
influence factors, 163
influencing factors, 138–41
initial available capacity, 157
initial charging current, 144
initial current, 164
initial performance, 180
initial polarization, 154–5, 157–8
initial SOC, 83
initial SOC state, 162
initial states, 153
instantaneous current, 240
insulation measurement, 242–6
insulation measurement methods, 243
insulation resistance, 245, 246
integrated scheme, 232–5
integrated starter generator (ISG), 271
intelligent temperature sensor, 237
<table>
<thead>
<tr>
<th>Term</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>internal combustion engine (ICE)</td>
<td>271</td>
</tr>
<tr>
<td>internal memory</td>
<td>65</td>
</tr>
<tr>
<td>internal resistance</td>
<td>18, 183</td>
</tr>
<tr>
<td>internal resistance difference</td>
<td>187</td>
</tr>
<tr>
<td>irreversible reactions</td>
<td>20</td>
</tr>
<tr>
<td>isolated circuit</td>
<td>242</td>
</tr>
<tr>
<td>Japan Electric Vehicle Association Standards (JEVS)</td>
<td>106, 107</td>
</tr>
<tr>
<td>judgment procedures</td>
<td>211</td>
</tr>
<tr>
<td>Kalman filter</td>
<td>61</td>
</tr>
<tr>
<td>Kalman filter method</td>
<td>54–5</td>
</tr>
<tr>
<td>key indicators</td>
<td>130</td>
</tr>
<tr>
<td>lead-acid batteries</td>
<td>125</td>
</tr>
<tr>
<td>least squares estimation (LSE)</td>
<td>59, 60</td>
</tr>
<tr>
<td>least-squares fitting</td>
<td>68</td>
</tr>
<tr>
<td>least squares method</td>
<td>25, 69</td>
</tr>
<tr>
<td>LIB cell</td>
<td>233</td>
</tr>
<tr>
<td>life</td>
<td>176–7</td>
</tr>
<tr>
<td>life cycle</td>
<td>34</td>
</tr>
<tr>
<td>LiFePO4 batteries</td>
<td>185–9</td>
</tr>
<tr>
<td>limited space</td>
<td>3</td>
</tr>
<tr>
<td>linear factor</td>
<td>151</td>
</tr>
<tr>
<td>linear influence factors</td>
<td>152</td>
</tr>
<tr>
<td>lithium cobalt oxide</td>
<td>2</td>
</tr>
<tr>
<td>lithium-ion battery</td>
<td>9–11, 76, 90, 108, 123–9</td>
</tr>
<tr>
<td>lithium iron phosphate (LFP)</td>
<td></td>
</tr>
<tr>
<td>Lithium-polymer</td>
<td>2</td>
</tr>
<tr>
<td>lithium manganate (LMO)</td>
<td>2</td>
</tr>
<tr>
<td>lithium nickel-manganese-cobalt (NMC) batteries</td>
<td>2</td>
</tr>
<tr>
<td>lithium titanate (LTO)</td>
<td>2</td>
</tr>
<tr>
<td>load voltage detection</td>
<td>50</td>
</tr>
<tr>
<td>look-up tables</td>
<td>51</td>
</tr>
<tr>
<td>low temperatures</td>
<td>134–5</td>
</tr>
<tr>
<td>Mas law charging method</td>
<td>128</td>
</tr>
<tr>
<td>mathematical expression</td>
<td>51</td>
</tr>
<tr>
<td>maximization</td>
<td>214, 222</td>
</tr>
<tr>
<td>maximization utilization</td>
<td>223</td>
</tr>
<tr>
<td>maximum available capacity</td>
<td>43, 47–50, 62, 70, 92, 196–7, 200–201, 205, 211–15</td>
</tr>
<tr>
<td>maximum available capacity (energy)</td>
<td>223</td>
</tr>
<tr>
<td>maximum available energy</td>
<td>87, 93, 96, 206, 207, 215–17</td>
</tr>
<tr>
<td>maximum charging capacity</td>
<td>132</td>
</tr>
<tr>
<td>maximum charging energy</td>
<td>91</td>
</tr>
<tr>
<td>maximum charging voltage</td>
<td>131</td>
</tr>
<tr>
<td>maximum current identification</td>
<td>172</td>
</tr>
<tr>
<td>maximum current selection</td>
<td>170–172</td>
</tr>
<tr>
<td>maximum discharging energy</td>
<td>91</td>
</tr>
<tr>
<td>maximum leakage current</td>
<td>243</td>
</tr>
<tr>
<td>maximum power</td>
<td>111</td>
</tr>
<tr>
<td>maximum voltage selection</td>
<td>169–170</td>
</tr>
<tr>
<td>measurement module</td>
<td>231</td>
</tr>
<tr>
<td>minimum capacity</td>
<td>208</td>
</tr>
<tr>
<td>model</td>
<td>228</td>
</tr>
<tr>
<td>model parameters identification</td>
<td>25</td>
</tr>
<tr>
<td>modern intelligent charging method</td>
<td>128–9</td>
</tr>
<tr>
<td>negative temperature coefficient resistors (NTC)</td>
<td>236</td>
</tr>
<tr>
<td>Nerst expanded model</td>
<td>23</td>
</tr>
<tr>
<td>neural network</td>
<td>57</td>
</tr>
<tr>
<td>no management</td>
<td>5</td>
</tr>
<tr>
<td>nominal capacity</td>
<td>44</td>
</tr>
<tr>
<td>non-dissipative converter</td>
<td>249</td>
</tr>
<tr>
<td>nonlinear factors</td>
<td>152–6</td>
</tr>
<tr>
<td>observation equation</td>
<td>54, 55, 81</td>
</tr>
<tr>
<td>OCV–SOC curve</td>
<td>149–50, 207</td>
</tr>
<tr>
<td>Ohm drop</td>
<td>77</td>
</tr>
<tr>
<td>Ohmic internal resistance</td>
<td>17–19, 31, 116–17</td>
</tr>
<tr>
<td>Ohm resistance</td>
<td>191–3</td>
</tr>
<tr>
<td>Ohm voltage drops</td>
<td>38, 88</td>
</tr>
<tr>
<td>onboard mode</td>
<td>266–7</td>
</tr>
<tr>
<td>open-circuit voltage (OCV)</td>
<td>11, 73, 101, 195–6</td>
</tr>
<tr>
<td>operating conditions hybrid electric vehicles</td>
<td>12–13</td>
</tr>
<tr>
<td>optimal charging</td>
<td>128</td>
</tr>
<tr>
<td>optimized CV charging</td>
<td>166</td>
</tr>
<tr>
<td>overcharge</td>
<td>124</td>
</tr>
<tr>
<td>over-charged</td>
<td>39, 181</td>
</tr>
<tr>
<td>over-current</td>
<td>39</td>
</tr>
<tr>
<td>over-discharged</td>
<td>181</td>
</tr>
<tr>
<td>overpotential</td>
<td>135</td>
</tr>
<tr>
<td>parallel battery SOCpar</td>
<td>190</td>
</tr>
<tr>
<td>parallel branch current</td>
<td>186–7</td>
</tr>
<tr>
<td>parallel connected</td>
<td>183–91, 193</td>
</tr>
<tr>
<td>parallel polarization voltage</td>
<td>186</td>
</tr>
<tr>
<td>passive ground detection</td>
<td>243–4</td>
</tr>
<tr>
<td>peak power</td>
<td>101–5, 108, 110–18, 120–121</td>
</tr>
<tr>
<td>performance indexes</td>
<td>163</td>
</tr>
<tr>
<td>permanent loss</td>
<td>136</td>
</tr>
<tr>
<td>Peukert formula</td>
<td>22</td>
</tr>
<tr>
<td>physical parameters</td>
<td>146</td>
</tr>
<tr>
<td>plateau area</td>
<td>32</td>
</tr>
<tr>
<td>plug-in electric vehicle (PEV)</td>
<td>191, 209</td>
</tr>
<tr>
<td>PNGV model</td>
<td>22, 28–31</td>
</tr>
<tr>
<td>polarization</td>
<td>15, 38, 183</td>
</tr>
<tr>
<td>amplitude</td>
<td>158–60</td>
</tr>
<tr>
<td>characteristics</td>
<td>29</td>
</tr>
<tr>
<td>impedance</td>
<td>152</td>
</tr>
<tr>
<td>resistance</td>
<td>17–19, 31, 139</td>
</tr>
</tbody>
</table>
voltage, 38, 40, 62–71, 73, 74, 77, 88, 133, 134, 144, 147–63, 170, 186, 199–200
voltage amplitude, 159
voltage control, 167–77, 168, 169
voltage difference, 194
polarizing time-constant, 65, 66
positive temperature coefficient resistors (PTC), 236
power
battery, 1
circuit, 246
density, 107
output, 182
takes trolley wires, 273
test, 109
power-up control, 255–6
practical application, 129
practical use, 194
pre-charging, 166
principles, 167–77
problems, 219–21
process noise, 80
production process, 180
pulse charging, 128
pure electric vehicles, 269
quantic function, 160
quantitative evaluation, 201–9
rapid replacement mode, 266–9
rate coefficient, 165
rated capacity, 132
rate discharge characteristics, 11
rated power test, 109
reaction mechanism, 9
real-time monitoring, 6
recyclable lithium ions, 46
redox reaction, 10, 76
relay switching, 231
remaining capacity, 46, 48, 49, 62, 208
remaining energy, 87, 92, 95–6
resistance, 264, 265
divider, 230–31, 241
method, 52–3
resting identification method, 147–8
resting time, 147, 154
Rint model, 28
safety management, 7
secondary batteries, 33
secondary side, 248
segmental linear functions, 51
selection, 164–5
self-adaptability, 171
self-adaptive algorithms, 61
self-discharge, 19, 20
series connected, 193
shepherd model, 23
shunt, 240–241
side reactions, 16, 136
simple management, 5
simulation model, 36
single cell, 210
slave module, 228
SOC–OCV curve, 175
spontaneous balance effect, 190
state equation, 34, 36, 54, 81
state of charge (SOC), 26, 38, 43, 44, 48–50, 73, 95, 115–16, 149, 160–163, 174, 183, 200–201, 221, 260
difference, 195
domain, 156–60
estimation, 6, 47, 56, 263
estimation validation, 70–74
gradient, 157, 158
levels, 162
of single cell, 217–18
SOC-based, 218
variance, 189
state of energy (SOE), 7, 43, 87, 91, 93–6
state of function (SOF), 7, 103
state of health (SOH), 7, 103, 155
state-space equations, 21
state space method, 54
structure, 138–41
support vector machine (SVM), 60–61
sweeping frequency, 265
Takagi–Sugeno fuzzy inference model, 58
temperature, 113–15, 146, 174, 259, 263
cabinet, 264
coefficient, 165
control, 258–9
measurement, 235–8
sensor, 238
terminal voltage, 101, 106
thermal resistance detector, 236
thermistor, 233, 237
thermocouple, 235
Thevenin model, 24, 28–30, 63
threshold values, 258, 259
time domain, 151
topology, 251
total voltage, 241–2
tracking calculating method, 149–50
traction battery technology, 274
traction power supply system, 273
traditional charging method, 172–7
transformation efficiency, 137
unbalanced branch current, 190
unbalanced current, 38, 185
Unnewehr model, 23
unscented Kalman filter method (UKF), 55
USABC battery test manual charging mechanism the battery module, 13
US Advanced Battery Consortium (USABC), 103
usage, 180–182

variable current, 141–3
  charging, 131–4, 133–4, 143, 173
  mode, 142
  verification, 85–7

voltage
  balance stratagem, 250
  control method, 127–8
  drop, 148, 191–3
  equalization, 250
  inconsistency, 35
  volt–ampere curve
    ΔQ/ΔV curve, 75

working current, 191
working environment, 3–4
working environment difference, 181