

Leseprobe

Christiani

Technical Institute for
Vocational Training

Henning Wagner · Reinhard Maier · Jürgen Schubert

Alternative Drive Systems – E-Mobility Basic training

Qualified Electrician for HV systems in Motor Vehicles

Hybrid and Electric Vehicles – Fuel Cell Vehicles



Dr.-Ing. Paul Christiani GmbH & Co. KG
www.christiani.de

Content

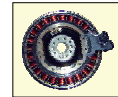
Content

1	Why do you have to have a high-voltage qualification to be allowed to work on modern vehicles with electric drives?	1
2	Which basic electrotechnical knowledge is it necessary to brush up on in order to be "fit" for work with the high-voltage technology in modern electric vehicles?	3
2.1	Introduction	3
2.1.1	Why electrically driven vehicles now?	3
2.1.2	What is the forecast for the future?	4
2.1.3	Which technology will prevail: "Hybrid", pure "Plug-in E-drive" or "Fuel cell"? . .	7
2.2	Storing electrical voltage	8
2.2.1	Nickel-cadmium battery (NiCd)	8
2.2.2	NiMH battery ... and its application in electrically driven vehicles	8
2.2.3	Lithium technology	10
2.2.4	Charging regulations	13
2.2.5	Cooling of high-voltage batteries	16
2.2.6	Vehicle battery calculation tasks	20
2.2.7	The capacitor as a charge and energy accumulator	24
2.2.8	Double-layer capacitors in the vehicle	25
2.2.9	What are capacitors required for in vehicle electric drives?	28
2.2.10	Capacitor for smoothing mixed voltages	28
2.2.11	Capacitor charging and discharge curve	30
2.2.12	The capacitor in the intermediate circuit of the inverter	31
2.3	Switching electrical currents electromagnetically	34
2.3.1	Speed and rotor position sensors	34
2.3.2	Rotors with permanent magnets	36
2.3.3	Contactors in electrically driven vehicles	37
2.3.4	Other safety relays/contactors in electric vehicles	41
2.4	Electronic components	43
2.4.1	The IGBT transistor	43
2.4.2	Using the IGBT transistor as an inverter in HV air conditioning compressors . .	44
3	What electrical machines and devices are used in electrically driven vehicles?	45
3.1	Generator	45
3.1.1	Voltage generation through induction of motion (generator principle)	45
3.1.2	What is three-phase current?	47
3.1.3	Three-phase generator (star connection and delta connection)	48
3.1.4	High-voltage generator in the vehicle	51
3.1.5	Rectifying as the first task of the inverter in electrically driven vehicles	52



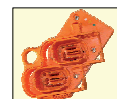
Content

3.2 DC/AC and DC/DC converters	53
3.2.1 Voltage generation through stationary induction (transformer principle)	53
3.2.2 Circuit diagram of an inverter in the vehicle (including DC/DC converter)	54
3.2.3 Structure and function of a simple DC/DC converter –Second task of the inverter: Raising or lowering HV voltage in the vehicle	55
3.2.4 Structure and function of a charge pump or a step-up converter in the vehicle	56
3.2.5 Function of a DC/AC converter with IGBT transistors	57
3.2.6 How does the inverter generate a sinusoidal three-phase current for a controllable rotating field? – Third task of the inverter in an electrically driven vehicle	58
3.3 Three-phase motor	61
3.3.1 The rotating field from the public grid	61
3.3.2 Creation of rotary movement in a three-phase motor	62
3.3.3 Principle of the synchronous three-phase motor	63
3.3.4 Examples of synchronous motor usage in HV vehicles	67
3.3.5 Asynchronous three-phase motor	71
3.3.6 Comparison of synchronous and asynchronous machines as disc-shaped motor generators for Mild Hybrid applications	73
3.3.7 Characteristic curves and operating behaviour of speed- and load-controlled three-phase motors in the vehicle	74
3.3.8 Power factor $\cos \varphi$ in three-phase motors	78
3.3.9 Asynchronous motor in the electric vehicle	80
3.3.10 How is a rotating field for a three-phase motor generated with direct current?	81
3.3.11 Vehicle HV on-board electrical systems	83
3.4 DC motor	84
3.4.1 Working principle of the DC motor	84
3.4.2 Structure and function of the DC motor	86
3.4.3 Counter-electromotive force (CEMF)	89
3.4.4 DC motor structure types	90
3.4.5 Starter diagram	92
3.4.6 Speed control	93
3.4.7 DC chopper controller	94
3.4.8 DC chopper controller in the electric vehicle	96
3.4.9 Uses of the DC motor in the vehicle	97
3.4.10 The starters as a special application in the vehicle	97
3.4.11 Brushless DC motors (BLDC)	98
3.4.12 The BLDC motor as a drive motor in electric vehicles	100
3.5 Wires, cables, connecting systems, charging devices	101
3.5.1 Wires, special specifications for HV cable	101
3.5.2 Protection for HV cables	103
3.5.3 Laying of HV cables	105
3.5.4 Electromagnetic compatibility (EMC) for HV cables	106
3.5.5 Connection systems for HV cables	107
3.5.6 Chargers for electric and plug-in hybrid vehicles	112



Content

3.5.7	Wiring example for a charger in a Smart ED	113
3.5.8	Charging stations	115
3.5.9	Charging cables and connectors for chargers for electric vehicles	119
3.5.10	Charging and battery replacement concepts	122
3.6	Drive concepts	125
3.6.1	Overview of different generator and starter systems	125
3.6.2	Overview of drive concepts	126
3.6.3	Development of the crankshaft starter generator as a precursor to the Mild Hybrid	127
3.6.4	Hybrid vehicle definition	128
3.6.5	Micro Hybrid	129
3.6.6	Mild Hybrid	129
3.6.7	Full or Strong Hybrid	130
3.6.8	Classification of vehicles according to arrangement of drives	130
3.7	Workshop work and diagnosis	139
3.7.1	Diagnosis using the workshop tester	139
3.7.2	Checking insulation resistance	140
3.7.3	Checking HV voltage	142
3.7.4	Checking manufacturer-specific HV voltage	142
3.7.5	Manufacturer-specific test units	143
3.7.6	Mechanical replacement work on high-voltage components	145
4	What are the hazards in the workshop for mechatronics engineers handling electrically driven vehicles and how are these dealt with?	149
4.1	Hazard due to the impact of electrical currents	149
4.1.1	Physiological effect of electrical current	149
4.1.2	Impact on the human organism	151
4.2	Hazard due to electric arc	152
4.2.1	Eye damage due to light intensity and radiation	153
4.2.2	Damage due to heat development	153
4.3	Hazard due to secondary accidents	153
4.4	Protective measures against electric shock and electric arcs in the public grid and in passenger cars	154
4.4.1	Definition/Classification of hazard classes	154
4.4.2	Hazard limits	156
4.4.3	Structure of electrical networks	156
4.4.4	Safety precautions in electrical installations and devices	158
4.4.5	Protective measures in passenger cars	163
4.4.6	Definition of "HV intrinsically safe vehicle"	164
4.4.7	Safety measures when working on high-voltage vehicles	167



Content

4.5	What to do in the event of accidents, first aid	171
4.5.1	Legal principles for assistance services	171
4.5.2	Process diagram of immediate life-saving measures	171
4.5.3	Self-protection as helper, rescue from danger zones	172
4.5.4	Diagram of emergency messages	172
4.5.5	Use of an AED (Automatic External Defibrillator)	173
5	What legal regulations must be taken into account when handling electrically driven vehicles in the workshop? What are the requirements for the workshop personnel?	175
5.1	Implications of the laws and regulations	175
5.1.1	Hazard assessment (risk assessment)	175
5.1.2	Determination of the hazard and measures	176
5.1.3	Operating instructions – Instructions for use – Product training by manufacturer	177
5.1.4	Training of the workshop personnel/trainees	179
5.1.5	Electrical disconnection of the affected vehicles (principle)	180
5.1.6	Ascertain and document disconnection from voltage	180
6	Description of the technology and of disconnection using examples from real series production vehicles	182
6.1	"Mild Hybrid" example: Mercedes S 400 Hybrid	182
6.1.1	Structure of the system with integration in the vehicle	182
6.1.2	Components	183
6.1.3	Auxiliary units concerned	185
6.1.4	Regenerative brakes	185
6.1.5	Regenerative braking system (RBS) circuit	187
6.1.6	Cooling of the HV units	190
6.1.7	Function and display of the flow of energy	191
6.1.8	Safety philosophy of the manufacturer	191
6.1.9	Disconnecting and ascertaining and documenting disconnection from voltage	192
6.2	"Full Hybrid" example: Toyota Prius with integration of motor generators in the transmission for the front drive	193
6.2.1	Overview of hybrid vehicle	193
6.2.2	Structure of the system with integration in the vehicle	195
6.2.3	Components and special features of the Toyota Prius	196
6.2.4	Tasks of the main components	197
6.2.5	Why is an inverter required?	198
6.2.6	Design of the combustion engine	199
6.2.7	Hybrid drive unit	200
6.2.8	Drive and driving situations	202
6.2.9	Nomographic diagram	207
6.2.10	Operation and display	209
6.2.11	12 V power supply and structure of the high-voltage on-board electrical system	211
6.2.12	Safety philosophy of the manufacturer	215



Content

6.3	"Electric vehicle" example: Smart ED (electric drive)	221
6.3.1	Brief overview of other electric vehicles	221
6.3.2	Components and special features of the smart fortwo ed	222
6.3.3	Explanations of the main components	223
6.3.4	Disconnecting and ascertaining and documenting disconnection from voltage	231
6.4	"Fuel cell vehicle" example: Mercedes B-Class F-Cell	233
6.4.1	Historical development	233
6.4.2	Fuel cell systems	234
6.4.3	How the PEM fuel cell works	235
6.4.4	Structure of a fuel cell stack	236
6.4.5	Schematic structure of a fuel cell vehicle	237
6.4.6	Processes in driving mode	238
6.4.7	Hydrogen storage systems	239
6.4.8	Efficiencies	241
6.5	Examples of other hybrid and electric vehicles	243
6.5.1	Mercedes Atego Hybrid as an example of the use of electric drives in the commercial vehicle sector	243
6.5.2	Electric bicycles	244
6.5.3	Electric scooters, electric bikes, electric tricycles	245
Appendix		247
7.1	Langenscheidt definitions of technical terms	247
7.2	Index of image sources	248
7.3	Index of key terms	249

