

Modeling and simulation of pure electric passenger vehicle based on Matlab and AVL CRUISE

ABSTRACT

In this paper, the vehicle control strategy of pure electric passenger vehicle is designed in MATLAB/simulink, and the driving control strategy and the braking recovery mode control strategy modeling and Simulation are analyzed in detail. The model of the pure electric passenger car is built in AVL CRUISE software, and the parameters of the pure electric passenger car, driving motor, power battery, car tire and other modules are set, and then the established modules are connected. The results show that the drive control strategy of pure electric passenger vehicle does have its unique practicability and superiority.

Keywords: pure electric passenger car; Vehicle control strategy; Co-Simulation; MATLAB/simulink; AVL CRUISE

1. INTRODUCTION

The control strategy of electric vehicle is a part of the controller of electric vehicle, and the control strategy is also a software way to improve the performance of electric vehicle. Foreign research on electric vehicle in this area is relatively early, so their research on the control strategy of electric vehicle also has a certain depth[1-7]. The University of Minnesota proposed a layered control strategy for electric vehicles, through which the economic performance of electric vehicles has been significantly improved. Yin D, Hori Y. et al. put forward the approximate calculation method of the maximum torque of pure electric vehicles, which improves the operational stability of pure electric vehicles to some extent. William T. Kirchner and others proposed to control the driving environment of electric vehicles and the real-time rotation of electric vehicles in order to achieve the cooperation between the driver and the car[8-10].

2. THE FORMULATION, MODELING AND SIMULATION OF THE WHOLE VEHICLE CONTROL STRATEGY FOR PURE ELECTRIC PASSENGER VEHICLES

The vehicle control system of pure electric passenger car is composed of the vehicle controller, cockpit controller and other subsystems. In the vehicle control system, the vehicle control strategy is the core of the control. The vehicle control strategy of pure electric passenger car is based on the analysis of the driver's operation intention and the analysis and integration of other modules in each vehicle. And then the collected information through complex processing and analysis, and finally to the other subsystem controller and their control components for coordination and control.

43 The system of pure electric passenger vehicle can be roughly divided into two categories,
44 one is the car power supply system, the other is the vehicle signal transmission part. The
45 system depressurizes the voltage generated by the power battery through the vehicle power
46 supply control part, so that the generated current can meet the requirements of pure electric
47 passenger vehicles. For the vehicle signal transmission part of pure electric passenger
48 vehicles, it collects the driver's driving intention and the current status signals of some small
49 modules of the car. These signals through the CAN communication system of the car, and
50 then the current information of the vehicle collected by the system is handed over to the
51 control system of the pure electric passenger car, which is analyzed and processed here to
52 achieve the control effect of the pure electric passenger car[11-12].

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54 2.1 Drive control strategy formulation

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56 The drive control strategy of pure electric passenger vehicles mainly depends on the
57 operator's intention, because it is necessary to take into account the safety of the power
58 battery and the drive motor of pure electric passenger vehicles at the same time, that is to
59 prevent the power battery output current from being too large and causing the power battery
60 damage, and prevent the motor temperature from being too high to burn out. It is the core
61 content of the pure electric vehicle control strategy to strictly meet the power target of the
62 pure electric passenger vehicle.

63 The index of the drive control strategy is to make the motor work as efficient as possible in
64 addition to meeting the above requirements, so as to reduce the loss of energy and improve
65 the driving range of the pure electric passenger car.

66 The output torque of the driving motor has a great relationship with the resistance of the car
67 on the way. When the car is driving on the road with a slope, the following dynamic equation
68 is obtained:

$$\frac{T_e i_0 \eta}{r} = F_t = F_f + F_i + F_w + F_j$$

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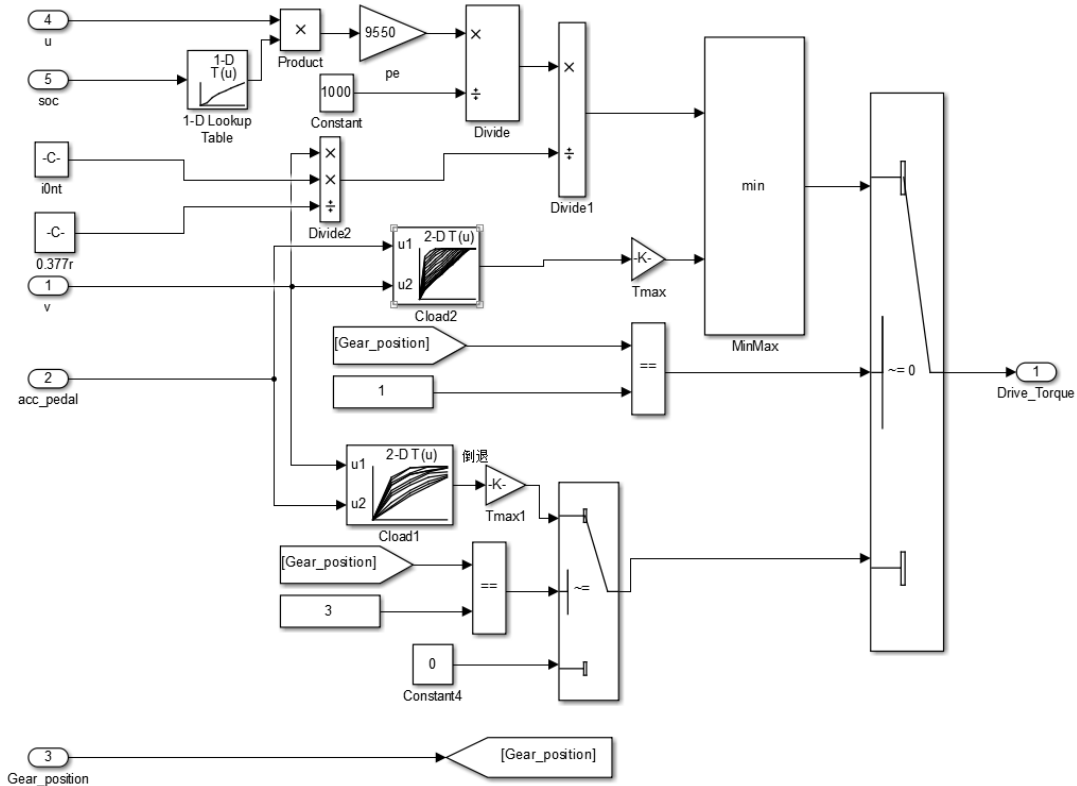
$$= Gf \cos \alpha + \frac{C_D A}{21.15} u_a^2 + G \sin \alpha + \delta m a \quad (2.1)$$

70 Because the road slope of the city is generally relatively small, $\cos \alpha \approx 1$, $\sin \alpha \approx \tan \alpha \approx i$, the
71 above equation is generally written as:

$$\frac{T_e i_0 \eta}{r} = Gf + \frac{C_D A}{21.15} u_a^2 + G i + \delta m a \quad (2.2)$$

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73 The drive control strategy of pure electric passenger cars mainly depends on the operation
74 intention of the car driver, because at the same time, it is necessary to take into account the
75 safety of the power battery and the drive motor of pure electric passenger cars, that is, to
76 prevent the power battery output current is too large and cause damage to the power
77 battery, and to prevent the motor temperature from being too high so that it burns out. To
78 strictly meet the power goals of pure electric passenger cars, is the core content of pure
79 electric vehicle control strategy. It is also possible to make the motor work efficiently to
80 reduce energy loss and improve the driving range of pure electric passenger cars. The
81 driving control strategy model of pure electric passenger car established in
82 MATLAB/Simulink software is shown in Figure1.

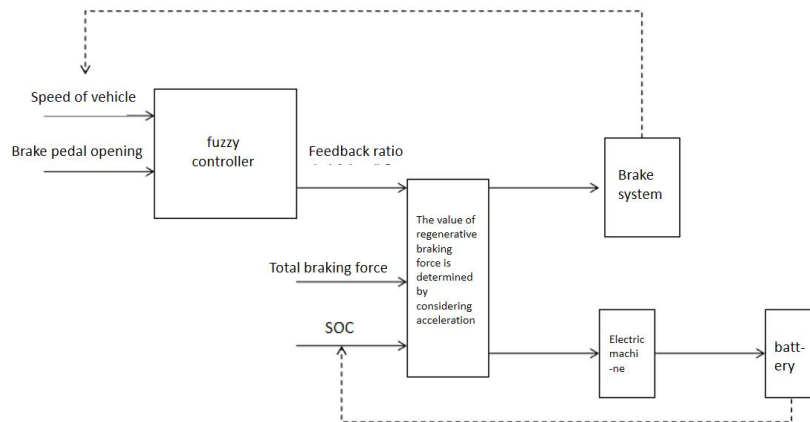


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Figure.1.drive control strategy model

2.2 Braking energy feedback control strategy

The speed of pure electric passenger vehicles, charge state SOC and brake pedal opening have a certain impact on the distribution of braking force. As can be seen from Figure 2, these modules also affect the determination of regenerative braking force under the premise of working together[13-15].

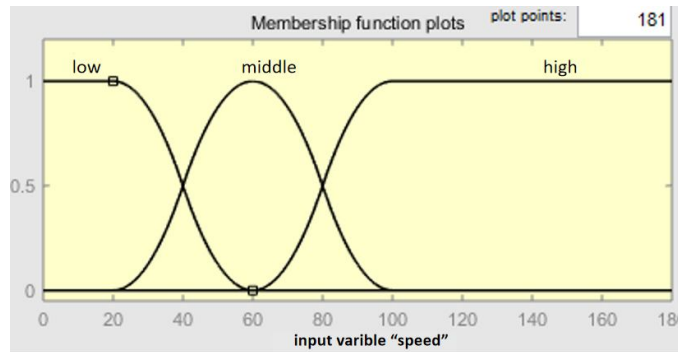


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Figure2.Braking energy feedback system

Here we choose fuzzy module in MATLAB for fuzzy control, and establish a fuzzy diagram in MATLAB/fuzzy module, as shown in Figure 3, Figure4 and Figure 5. Taking the speed of pure electric passenger car as an example, when the speed of the car is 40km/h, it can be

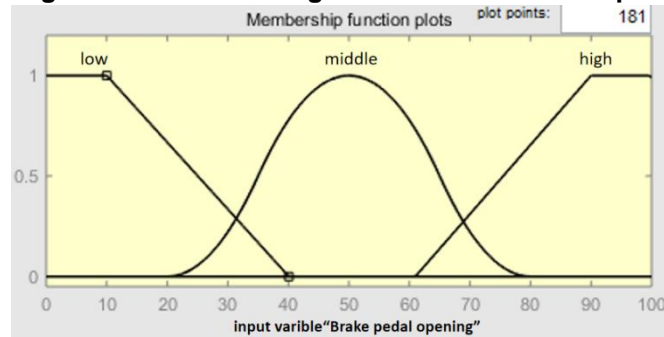
96 seen that about 0.5 belongs to the "low" range, and about 0.5 belongs to the "medium"
 97 range.



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Figure 3 Schematic diagram of the division of speed

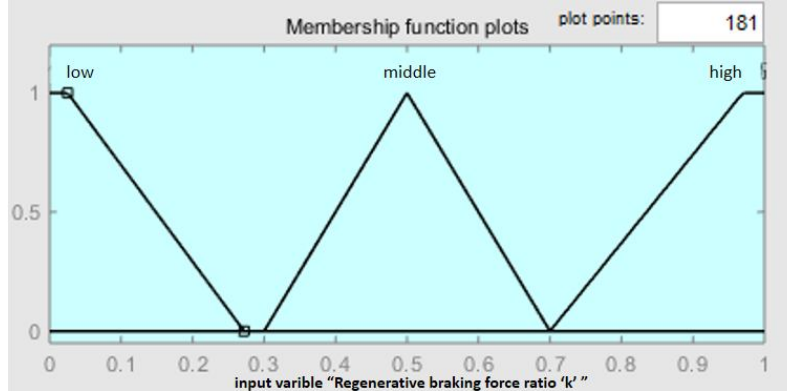


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Figure.4.Schematic diagram of division of brake pedal opening



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Figure.5.Schematic diagram of the division of regenerative braking force ratio ' k '

105 When setting the implementation rule of brake energy feedback mode in fuzzy control, it is
 106 necessary to meet the intention of the driver as much as possible, so as to ensure the safety
 107 and comfort of the pure electric passenger car, and to ensure that as much energy as
 108 possible can be recovered to make the pure electric passenger car have a longer driving
 109 range[16-17].

111 According to the actual life experience, and by referring to a large number of relevant
 112 studies, the fuzzy rules summarized here are as follows:

113 (1).If(speed is low)and(brake pedal opening is low)then(regenerative braking force ratio k is
 114 low);

115 (2).If(speed is low)and(brake pedal opening is medium)then(regenerative braking force ratio
 116 k is low);

117 (3).If(speed is low)and(brake pedal opening is high)then(regenerative braking force ratio k is
 118 medium);
 119 (4).If(speed is medium)and(brake pedal opening is low)then(regenerative braking force ratio
 120 k is low);
 121 (5).If(speed is medium)and(brake pedal opening is medium)then(regenerative braking force
 122 ratio k is medium);
 123 (6).If(speed is medium)and(brake pedal opening is high)then(regenerative braking force ratio
 124 k is medium);
 125 (7).If(speed is high)and(brake pedal opening is low)then(regenerative braking force ratio k is
 126 medium);
 127 (8).If(speed is high)and(brake pedal opening is medium)then(regenerative braking force ratio
 128 k is high);
 129 (9).if (speed is high)and(brake pedal opening is high)then(regenerative braking force ratio k
 130 is high)
 131 The basic rule is that when the car speed is very low or the brake pedal opening is relatively
 132 small, the regenerative braking force can be generated is small. If the brake pedal opening
 133 of pure electric passenger cars remains unchanged, the car speed increases, and the
 134 proportion of regenerative braking force will increase. However, due to the operating power
 135 of the driving motor is limited, in order to ensure that the motor works in the rated power,
 136 When the speed of the car reaches a certain value, the regenerative braking proportion of
 137 the energy feedback system will not continue to increase, and will remain at the maximum.
 138 in the future. These Settings not only meet the requirements of real working conditions, but
 139 also ensure the driver's brake comfort requirements.

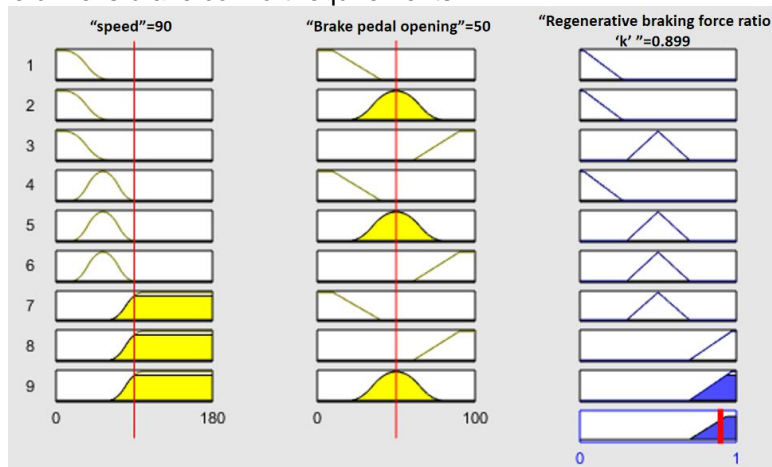


Figure.6.Fuzzy rule distribution diagram

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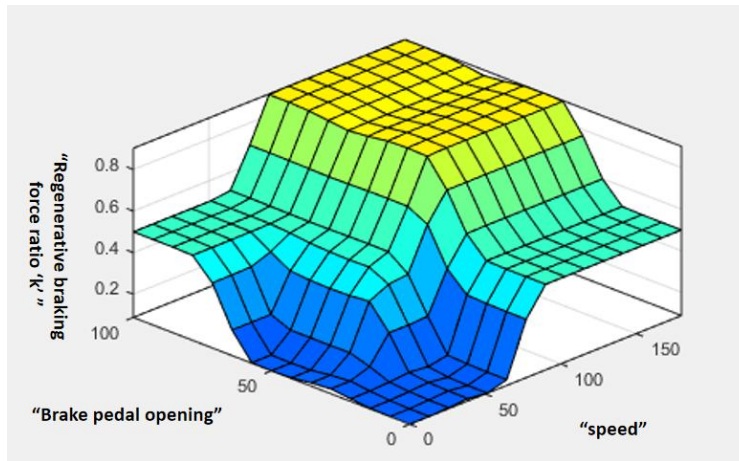


Figure.7.Fuzzy rule response MAP surface

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The braking energy feedback model in MATLAB/simulink is shown in Figure 8.

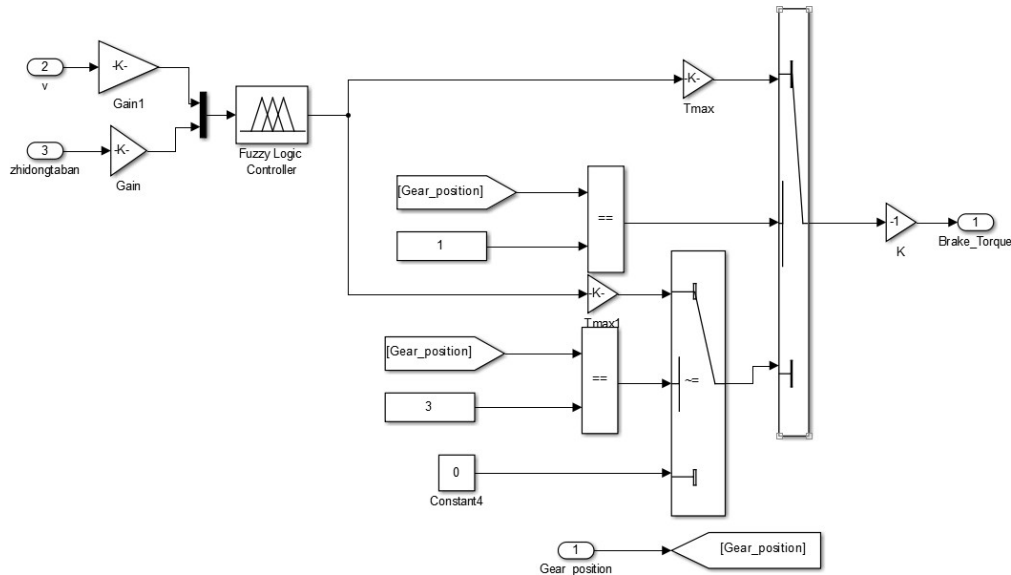


Figure.8. Brake energy feedback model

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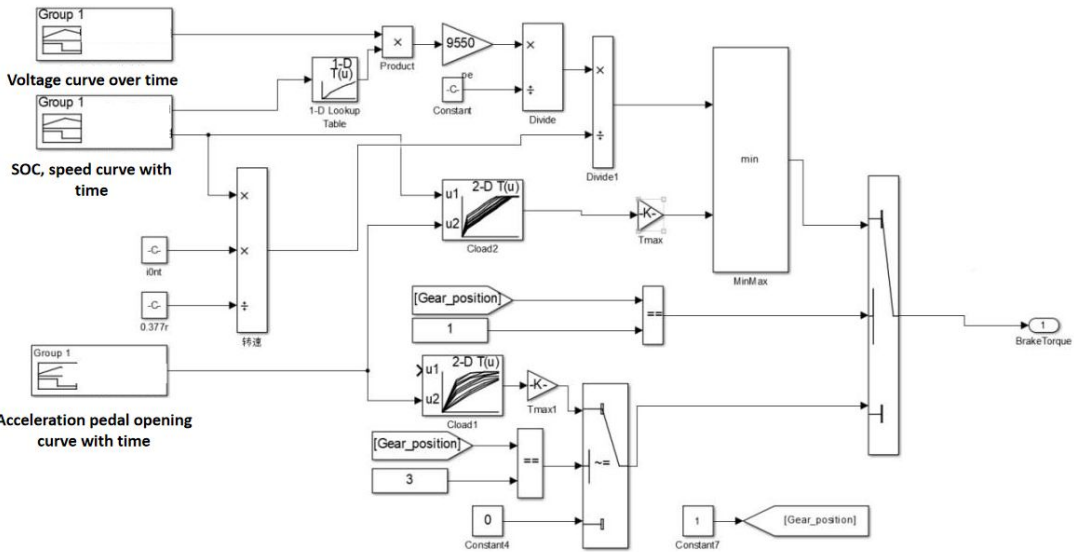
3. SIMULATION OF DRIVE CONTROL AND BRAKE CONTROL STRATEGY

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3.1 Drive control strategy formulation

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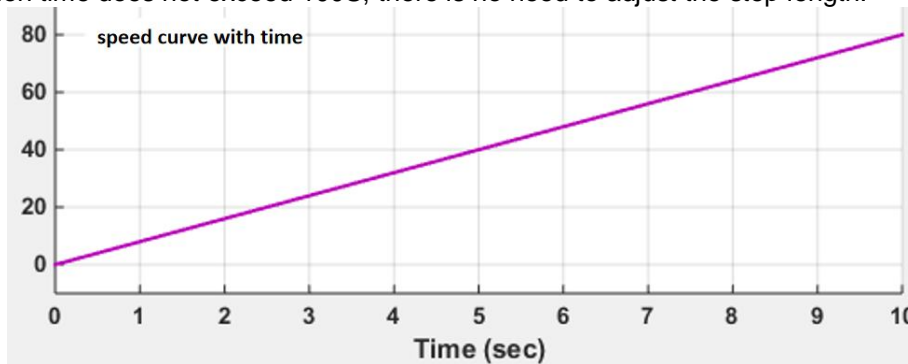
In the Simulation of drive control strategy, it is necessary to make MATLAB/SIMULINK simulate the signal of speed change with time, the signal of acceleration pedal change with time, the signal of battery SOC state and battery voltage change with time[18]. If the gear is forward gear D (1), the speed change curve with time is shown in Figure 10, the acceleration pedal change curve with time is shown in Figure 11, and the input curve of battery SOC (%) change with time is shown in Figure 12, and the battery voltage change curve with time is shown in Figure 13. At this time, the Simulation picture of the drive control strategy is shown in Figure 9.



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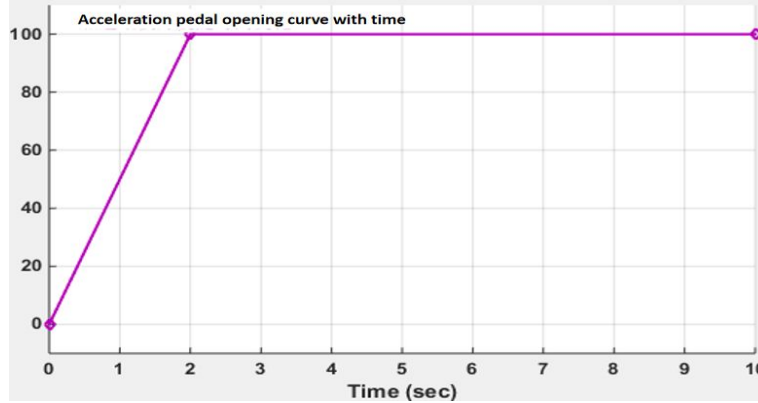
Figure.9.Driver control policy Simulation diagram

Among them, according to the driver's operating habits, it takes about 2s for the opening of the accelerator pedal to increase from 0 to 100% when accelerating steadily from a standstill to 80km/h. After that, we keep the opening at 100%, that is, let the accelerator pedal pedal to the end. At this time, the Simulation execution time is set to 40S, because the execution time does not exceed 100S, there is no need to adjust the step length.



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Figure.10.Relationship between vehicle speed and time in D-gear



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Figure.11.The relationship between acceleration pedal and time is in D gear

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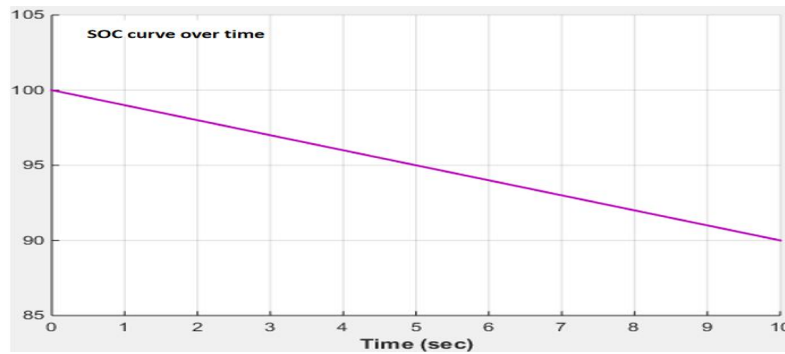


Figure 12 Relationship between battery soc and time in D-gear

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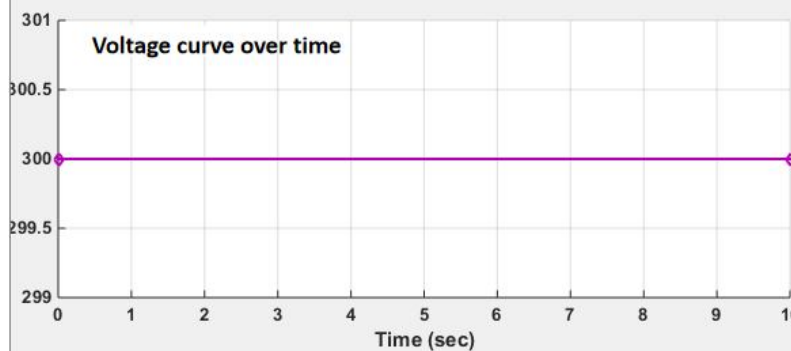
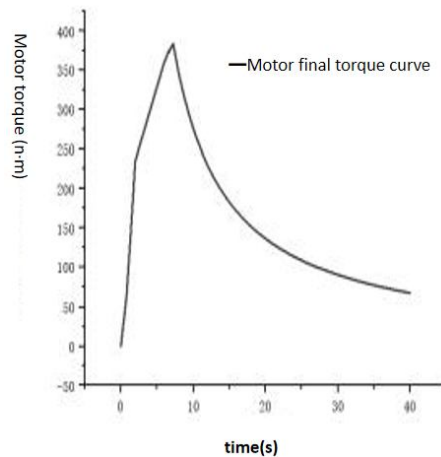


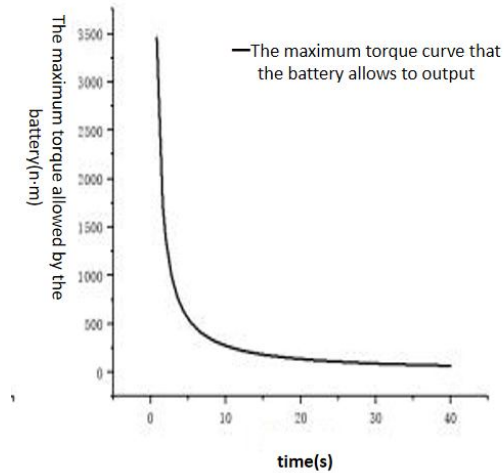
Figure.13. Relationship between battery voltage and time in D-gear

175 In this state, the output images of the final output torque of the motor and the allowable
176 output torque of the battery are shown in Figure 14,15 respectively. It can be seen that in the
177 first 2s, the throttle makes the motor torque change rate is very large, when the accelerator
178 pedal is stepped on to 100%, the accelerator pedal opening remains unchanged, at this time
179 the car is still accelerating, so the motor demand torque is still increasing, when the time
180 reaches about 7s, The maximum torque allowed by the maximum output of the battery is
181 reduced to less than the required torque, so due to the influence of the battery on the
182 maximum output torque, the final torque of the motor mutates, and with the passage of time,
183 the final torque of the motor is also decreasing.



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Figure.14. Final motor torque change curve

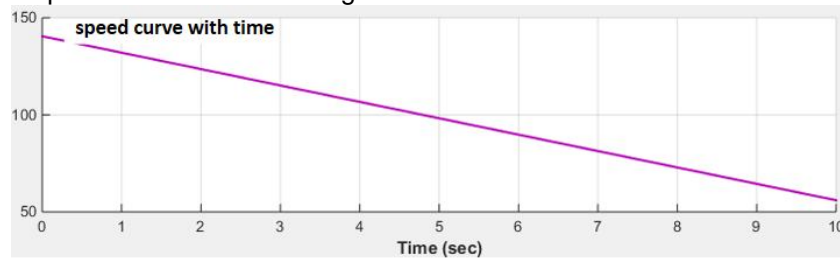


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187 **Figure.15. Maximum output torque allowed by the battery**
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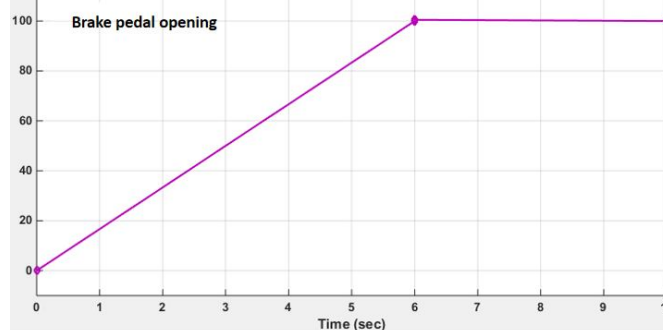
189 **3.2 Simulation of brake control strategy**
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191 When the input signal is simulated to the curve with time of vehicle speed as shown in
192 Figure.16, and the curve with time of accelerator pedal opening as shown in Figure.17, the
193 curve with time of compensation torque is shown in Figure.18.

194 Since the speed is not suitable for slamming on the brake when the speed is very
195 high, we let the accelerator pedal opening gradually step down in 6 seconds, so that the car
196 will not sideslip due to too much braking force and cause an accident.



197 **Figure.16.Simulation signal of speed curve over time**
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199 **Figure.17.Brake pedal curve with time Simulation signal**
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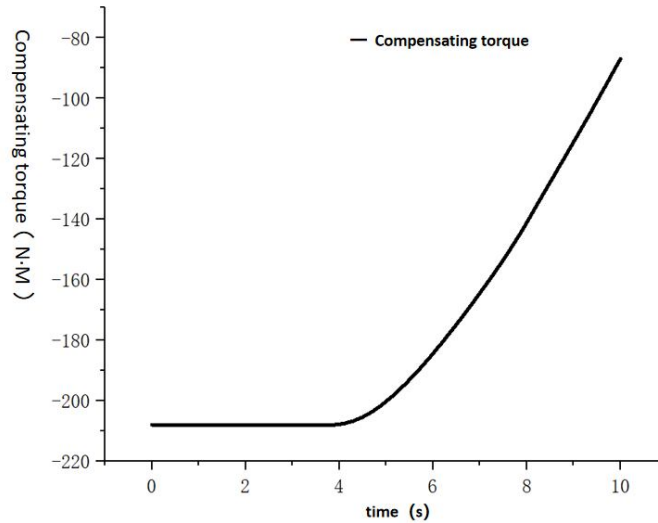


Figure.18.Compensation torque curve over time

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When the speed gradually decreases with the passage of time, and the opening of the brake pedal gradually increases with time, the torque of the braking recovery energy of the vehicle will also gradually decrease with time. Because the minimum speed of the speed set by the analog signal is not a certain limit speed at this time, the recovery energy torque will not become 0.

4. CRUISE-BASED VEHICLE MODEL CONSTRUCTION AND INTEGRATION WITH DRIVE CONTROL STRATEGY

4.1 Cruise-based vehicle model building

In AVL CRUISE, the vehicle model building of pure electric passenger cars mainly includes the following steps: first, the selection of each module of the vehicle; Second, establish the mechanical connection and electrical connection between each module of the vehicle; Third, establish the signal connection between each module of the vehicle; Fourth, set the detailed parameters in the various modules of the car established before. By analyzing the function and structure of the vehicle, the corresponding components in the CRUISE software component library are determined according to the structure of the vehicle power system, and the components are dragged to the modeling window. The main modules used are power battery module, drive motor module, differential module, vehicle brake module, car wheel module, driver's cockpit module, display module, control model Matlab DLL and so on [19-20].

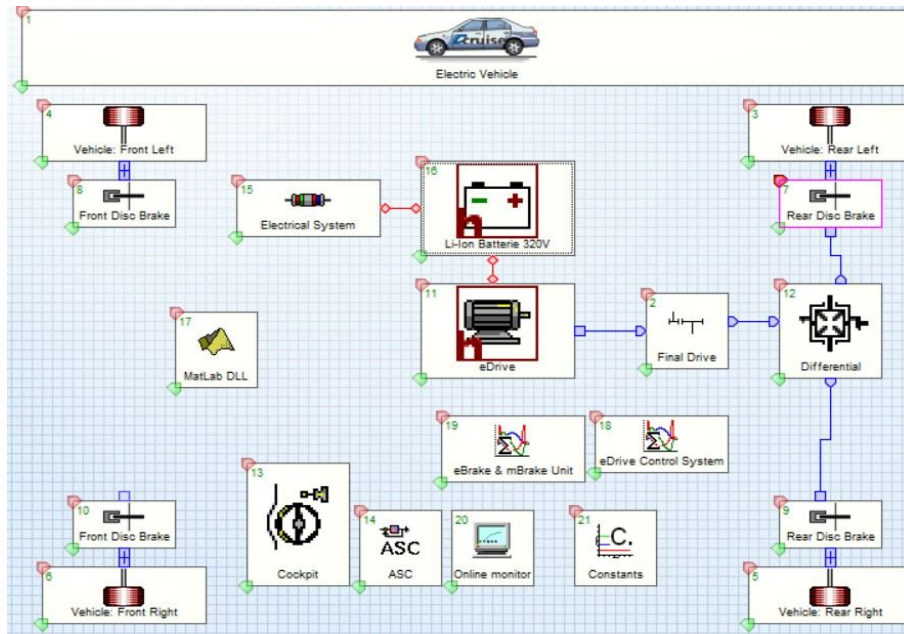


Figure.19.pure electric vehicle Simulation model

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227 4.2 CRUISE vehicle module parameter setting

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229 After building a pure electric passenger car model in AVL CRUISE and completing various
 230 connections between various modules of the car, parameters of the vehicle module, drive
 231 motor module, power battery module, driver's cockpit module, transmission system module
 232 and vehicle wheel module can be set[21-23].

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234 4.3 The drive control strategy simulink model is integrated with the whole 235 vehicle CRUISE model

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237 After modeling the control strategy of pure electric passenger car in MATLAB/simulink and
 238 building the whole vehicle model of pure electric passenger car in AVL CRUISE, it is
 239 necessary to verify the practicability and effectiveness of the developed drive control
 240 strategy of pure electric passenger car. Here, it is necessary to jointly simulate the pure
 241 electric passenger car drive control strategy and the pure electric passenger car complete
 242 vehicle model built in AVL CRUISE in MATLAB/simulink, and deliver the Simulation results
 243 to the complete vehicle model built in AVL CRUISE through the set output port. After all the
 244 processes described above, the entire Simulation process can be completed.

245 The calculation result of the maximum speed of pure electric passenger car is a relatively
 246 accurate result obtained after the joint Simulation of MATLAB/simulink and AVL CRUISE.
 247 When analyzing and calculating the maximum speed of pure electric passenger car, the car
 248 is required to be carried out under the condition of uniform full load. At the same time, it is
 249 also necessary to remove the driving resistance and the influence of road ramps during the
 250 driving process of the car. The calculation results of the acceleration task of the co-
 251 Simulation car are shown in Figure 20, and it can be clearly seen that when the car starts,
 252 the acceleration of the vehicle is 6.1, and the driving speed of the car reaches 50km/h. The
 253 acceleration of the car began to slowly decrease, and the pure electric passenger car
 254 accelerated for a period of time, about 20S, and finally the maximum speed of the pure
 255 electric passenger car reached 180km/h.

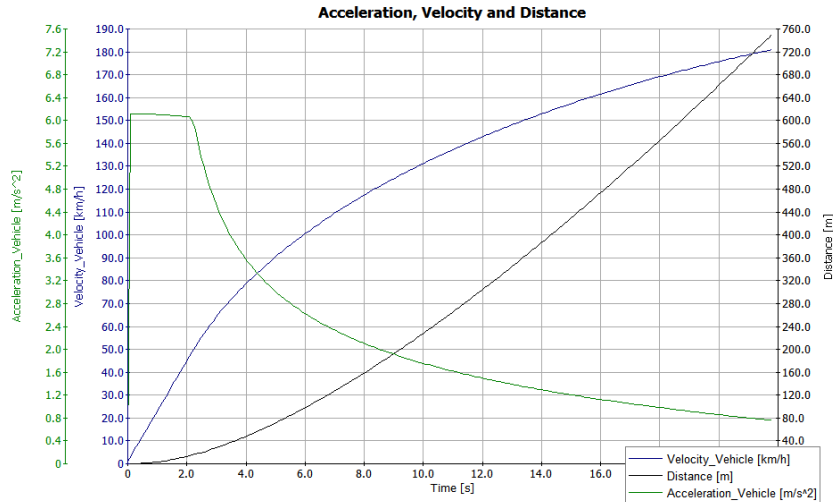


Figure.20. Acceleration, speed, and distance curve

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 258 When analyzing the Simulation results of Acceleration performance of pure electric
 259 passenger car from stationary to 100km/h, after setting the target parameter in the left Full
 260 Load Acceleration calculation module of AVL CRUISE Simulation software, the driving
 261 speed of pure electric passenger car is set to gradually accelerate from stationary. Among
 262 them, the acceleration task of the vehicle is set to 0-100km/h, and then 10 intervals are set
 263 here, and the interval of each interval is 10km/h, and then all the Simulation parameters that
 264 need to be set are set, and finally the joint Simulation is carried out. It can be seen in the
 265 following figure that when the control strategy is added to the vehicle model established in
 266 AVL CRUISE, the acceleration performance calculation results of the co-Simulation are
 267 shown in Figure 21.

Measuring Points VELOCITY

Velocity	Gear	Time	Distance	Speed	Measured Speed Ratio
<km/h>	<->	<s>	<m>	<l/min>	<->
10.00	1	0.41	0.63	664.47	0.00
20.00	1	0.86	2.52	1328.93	0.00
30.00	1	1.32	5.69	1993.40	0.00
40.00	1	1.77	10.12	2657.87	0.00
50.00	1	2.23	15.86	3322.34	0.00
60.00	1	2.75	23.77	3986.80	0.00
70.00	1	3.37	35.04	4651.27	0.00
80.00	1	4.11	50.39	5315.74	0.00
90.00	1	4.96	70.59	5980.21	0.00
100.00	1	5.95	96.57	6644.67	0.00
110.00	1	7.07	129.37	7309.14	0.00
120.00	1	8.35	170.34	7973.61	0.00
130.00	1	9.81	221.06	8638.08	0.00
140.00	1	11.48	283.60	9302.54	0.00
150.00	1	13.39	360.79	9967.01	0.00
160.00	1	15.62	456.67	10631.48	0.00
170.00	1	18.24	577.18	11295.95	0.00
180.00	1	21.44	732.78	11960.41	0.00

268
 269 **Figure 21 Acceleration performance from 0 to 100km/h with the control policy**
 270

271 **5. CONCLUSION**

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 273 The whole vehicle control strategy of pure electric passenger car is designed in
 274 MATLAB/simulink. The driving control strategy and the control strategy modeling and
 275 Simulation of braking energy recovery mode are analyzed in detail. The model of pure
 276 electric passenger car was built in AVL CRUISE software, and parameters were set for
 277 modules such as pure electric passenger car, drive motor, power battery, and automobile

278 tire. After that, all modules were connected, including physical connection and electrical
279 connection between modules. The most important step before co-Simulation is as follows:
280 That's the signal connection. In AVL CRUISE software, the drive control strategy of the pure
281 electric passenger car designed in advance is imported into MATLAB/simulink software, and
282 AVL CRUISE software makes a joint analysis to analyze the economic and dynamic
283 performance of the pure electric passenger car through the set calculation tasks. It is
284 concluded that the drive control strategy of pure electric passenger car has its unique
285 practicability and superiority.
286

287 **COMPETING INTERESTS**

288
289 Authors have declared that no competing interests exist.
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291 **AUTHORS' CONTRIBUTIONS**

292
293 This work was carried out in collaboration among all authors. All authors read and approved
294 the final manuscript.
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