Journal of Engineering Research and Reports

Volume 25, Issue 5, Page 41-54, 2023; Article no.JERR.102341
ISSN: 2582-2926

Modeling and Simulation of Pure Electric Passenger Vehicle Based on MATLAB and AVL CRUISE

Gong Ping [a*]

[a] *School of Mechanical Engineering, North China University of Water Resources and Electric Power, Zhengzhou, China.*

Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JERR/2023/v25i5910

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/102341

Short Research Article

Received: 25/04/2023
Accepted: 28/06/2023
Published: 05/07/2023

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.

**Corresponding author: Email: ncwu2021gp@163.com;*

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.

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

2.1 Drive Control Strategy Formulation

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

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

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

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

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

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

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

The drive control strategy of pure electric passenger cars mainly depends on the operation intention of the car driver, because at the same time, it is necessary to take into account the safety of the power battery and the drive motor of pure electric passenger cars, that is, to prevent the power battery output current is too large and cause damage to the power battery, and to prevent the motor temperature from being too high so that it burns out. To strictly meet the power goals of pure electric passenger cars, is the core content of pure electric vehicle control strategy. It is also possible to make the motor work efficiently to reduce energy loss and improve the driving range of pure electric passenger cars.The driving control strategy model of pure electric passenger car established in MATLAB/Simulink software is shown in Fig. 1.

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 Fig. 2, these modules also affect the determination of regenerative braking force under the premise of working together [13-15].

Here we choose fuzzy module in MATLAB for fuzzy control, and establish a fuzzy diagram in MATLAB/fuzzy module, as shown in Fig. 3, Fig. 4 and Fig. 5. Taking the speed of pure electric passenger car as an example, when the speed of the car is 40km/h, it can be seen that about 0.5 belongs to the "low" range, and about 0.5 belongs to the "medium" range.

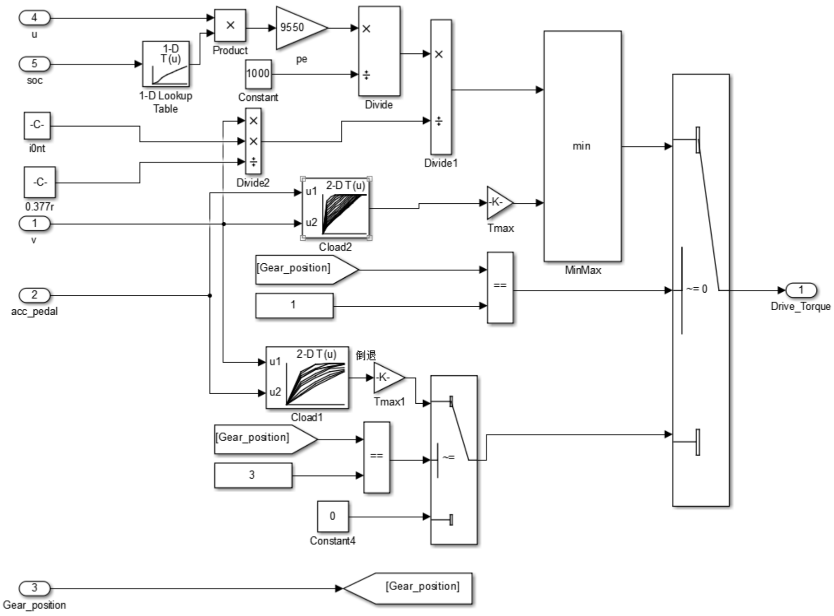

Fig. 1. Drive control strategy model

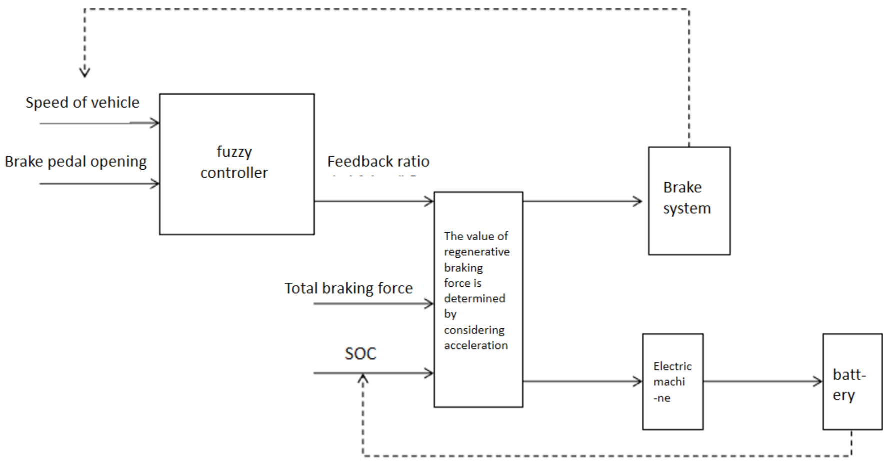

Fig. 2. Braking energy feedback system

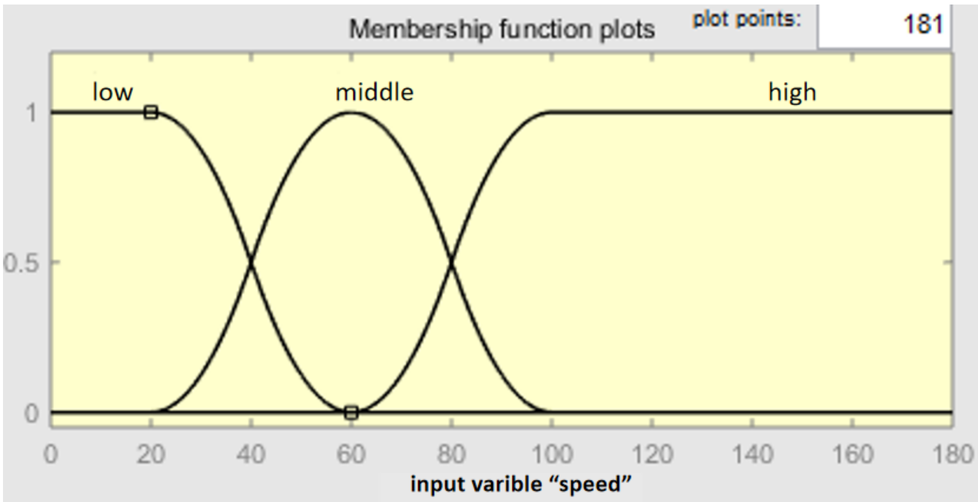

Fig. 3. Schematic diagram of the division of speed

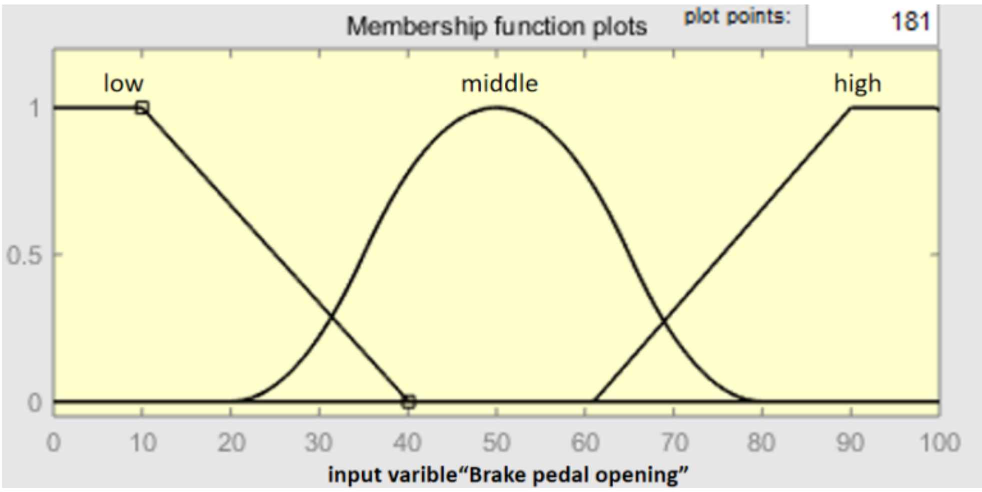

Fig. 4. Schematic diagram of division of brake pedal opening

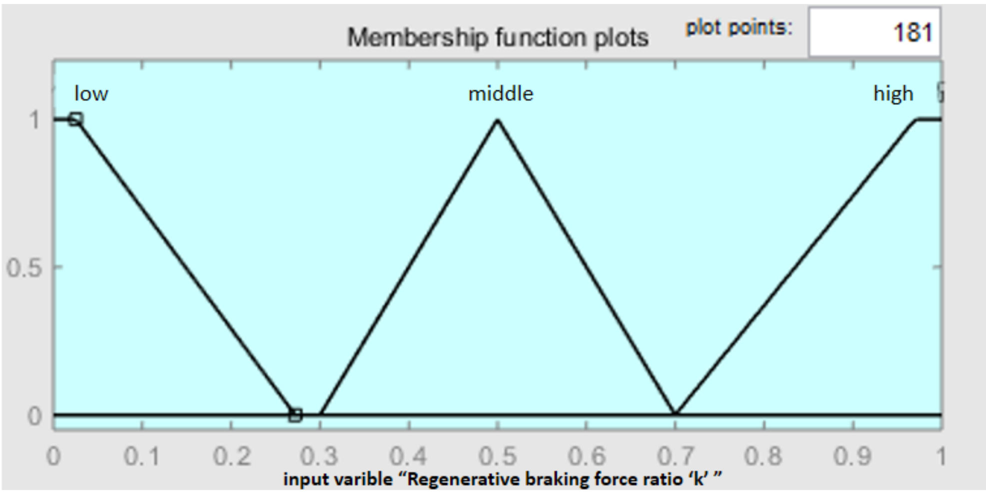

Fig. 5. Schematic diagram of the division of regenerative braking force ratio 'k'

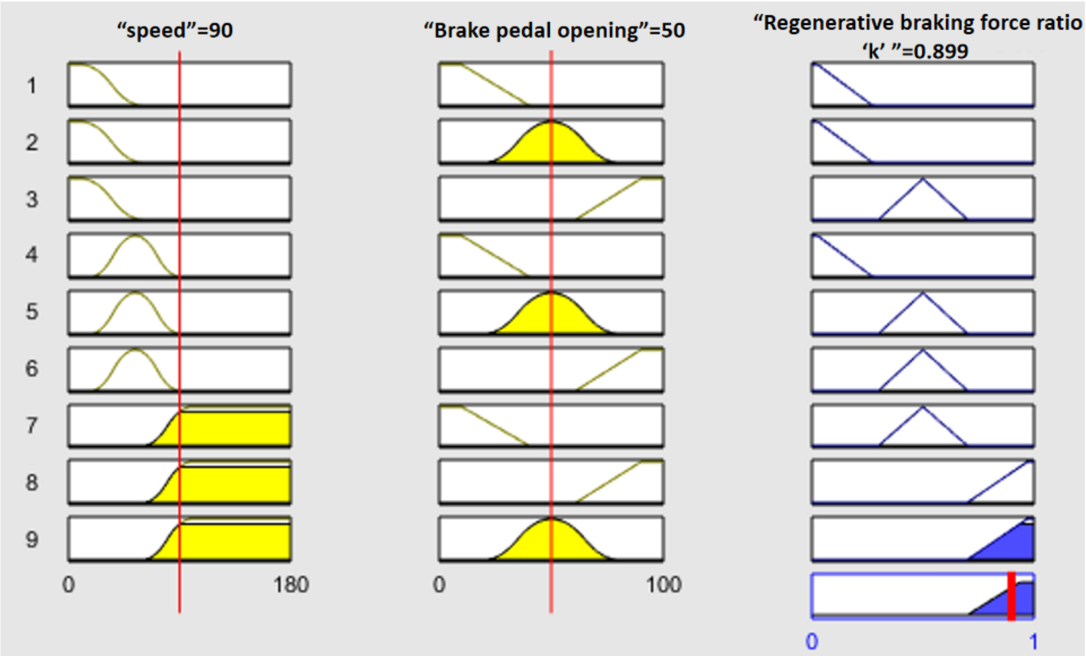

Fig. 6. Fuzzy rule distribution diagram

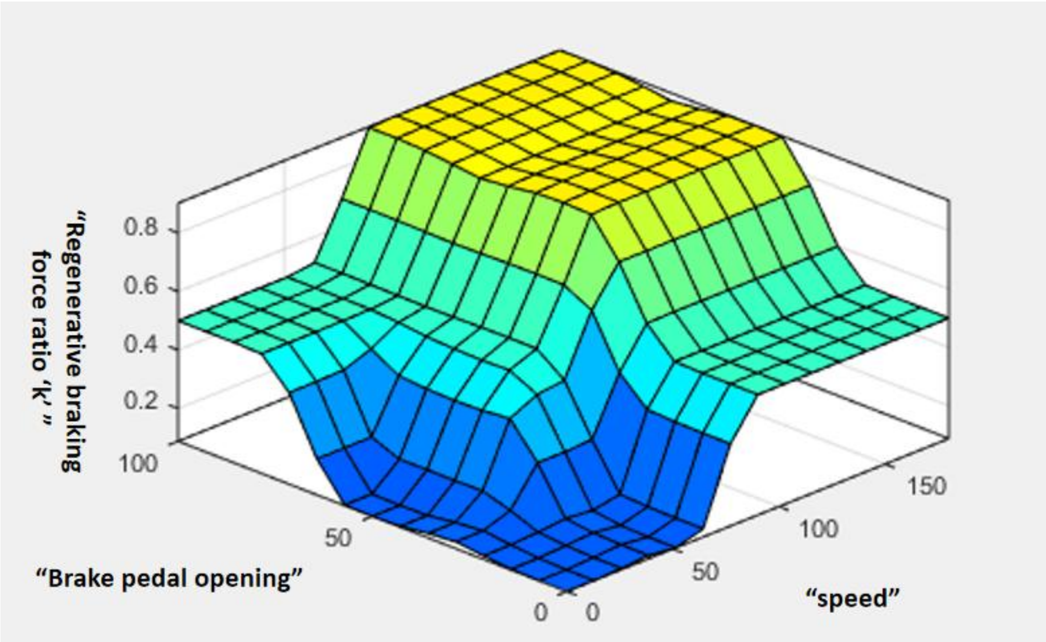

Fig. 7. Fuzzy rule response MAP surface

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

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

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

2. If(speed is low)and(brake pedal opening is medium)then(regenerative braking force ratio k is low);
3. If(speed is low)and(brake pedal opening is high)then(regenerative braking force ratio k is medium);
4. If(speed is medium)and(brake pedal opening is low)then(regenerative braking force ratio k is low);
5. If(speed is medium)and(brake pedal opening is medium)then(regenerative braking force ratio k is medium);
6. If(speed is medium)and(brake pedal opening is high)then(regenerative braking force ratio k is medium);
7. If(speed is high)and(brake pedal opening is low)then(regenerative braking force ratio k is medium);
8. If(speed is high)and(brake pedal opening is medium)then(regenerative braking force ratio k is high);
9. if (speed is high)and(brake pedal opening is high)then(regenerative braking force ratio k is high);

The basic rule is that when the car speed is very low or the brake pedal opening is relatively small, the regenerative braking force can be generated is small. If the brake pedal opening of pure electric passenger cars remains unchanged, the car speed increases, and the proportion of regenerative braking force will increase. However, due to the operating power of the driving motor is limited, in order to ensure that the motor works in the rated power, When the speed of the car reaches a certain value, the regenerative braking proportion of the energy feedback system will not continue to increase, and will remain at the maximum。 in the future. These Settings not only meet the requirements of real working conditions, but also ensure the driver's brake comfort requirements. The braking energy feedback model in MATLAB/simulink is shown in Fig. 8.

3. SIMULATION OF DRIVE CONTROL AND BRAKE CONTROL STRATEGY

3.1 Drive Control Strategy Formulation

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 Fig. 10,the acceleration pedal change curve with time is shown in Fig. 11, and the input curve of battery SOC (%) change with time is shown in Fig. 12, and the battery voltage change curve with time is shown in Fig. 13. At this time, the Simulation picture of the drive control strategy is shown in Fig. 9.

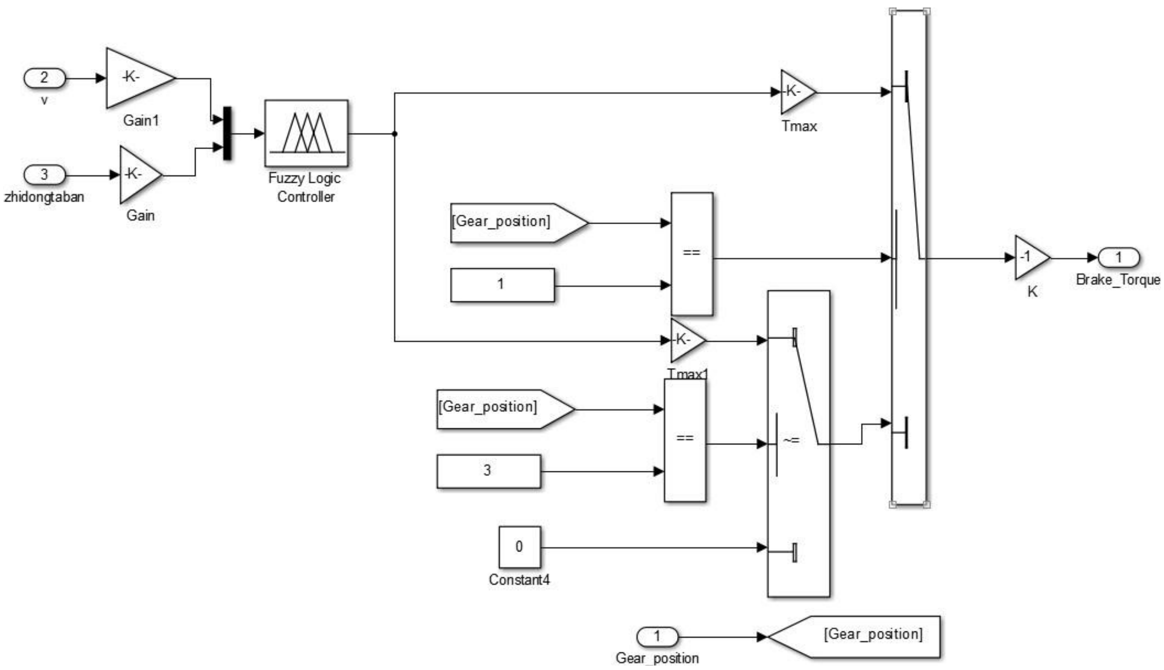

Fig. 8. Brake energy feedback model

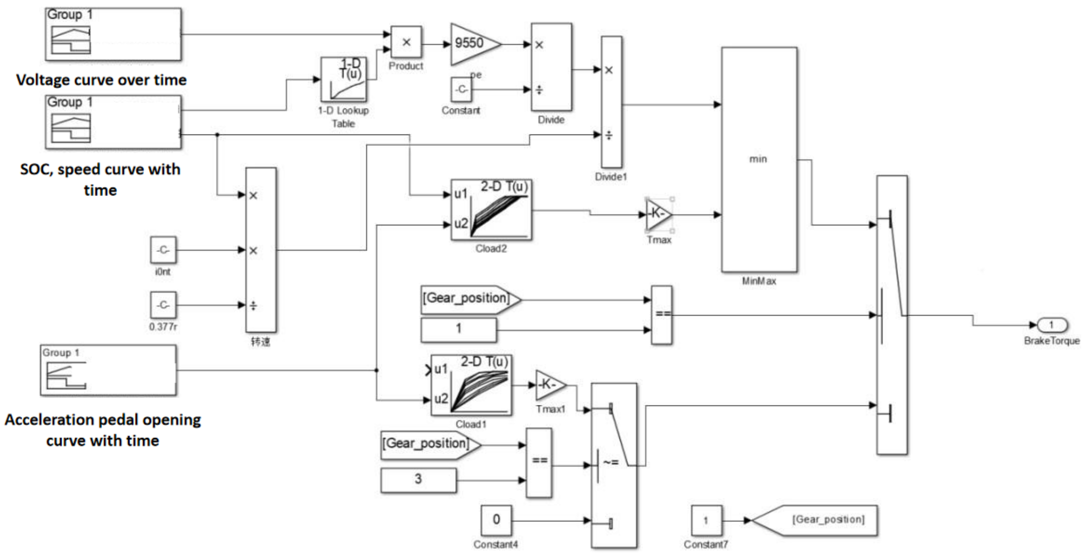

Fig. 9. Driver control policy Simulation diagram

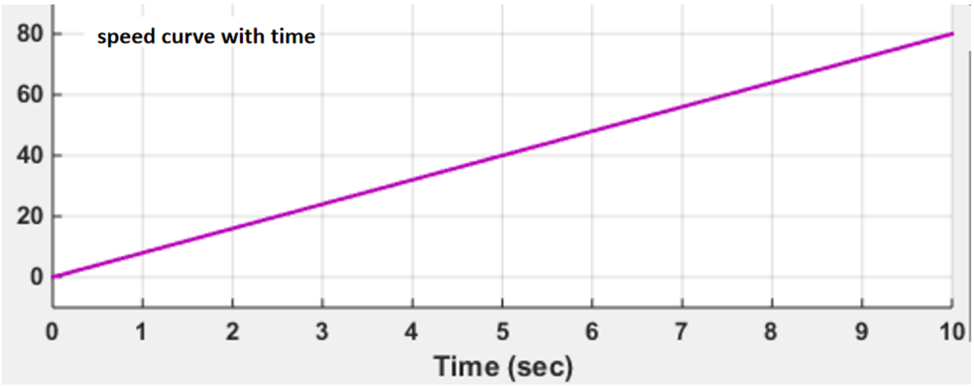

Fig. 10. Relationship between vehicle speed and time in D-gear

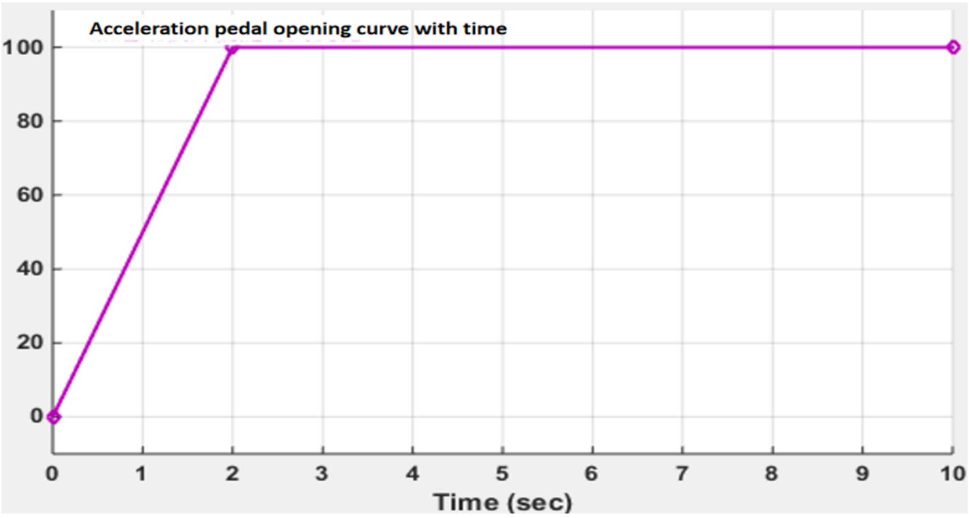

Fig. 11. The relationship between acceleration pedal and time is in D gear

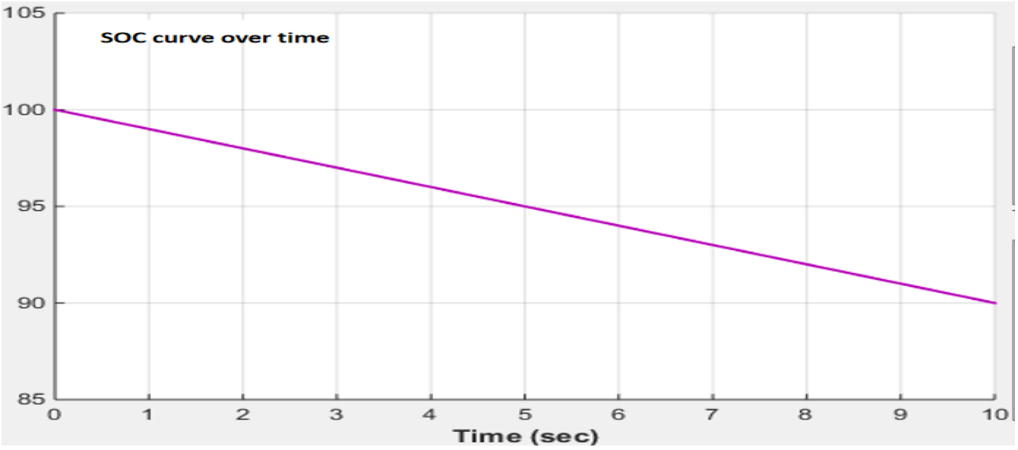

Fig. 12. Relationship between battery soc and time in D-gear

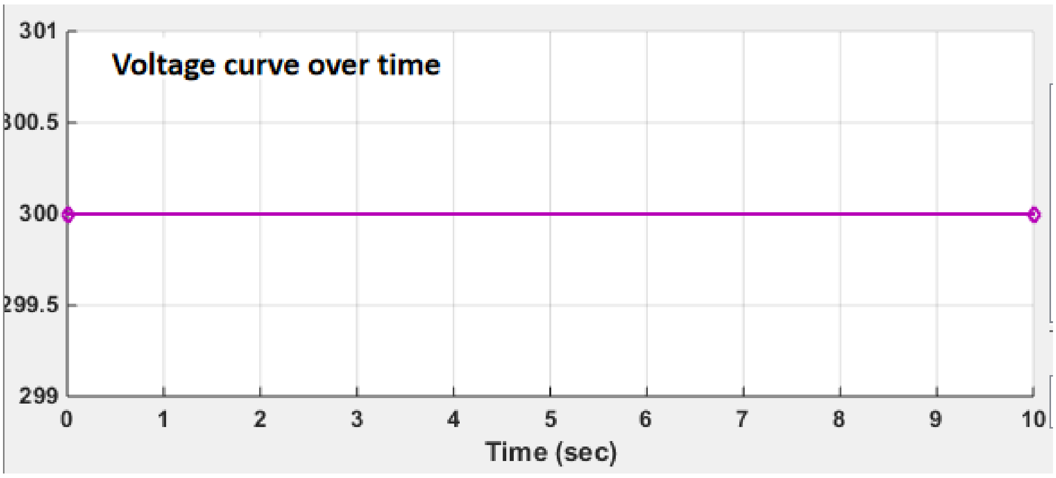

Fig. 13. Relationship between battery voltage and time in D-gear

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 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.

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

3.2 Simulation of Brake Control Strategy

When the input signal is simulated to the curve with time of vehicle speed as shown in Fig.16, and the curve with time of accelerator pedal opening as shown in Fig.17, the curve with time of compensation torque is shown in Fig.18.

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

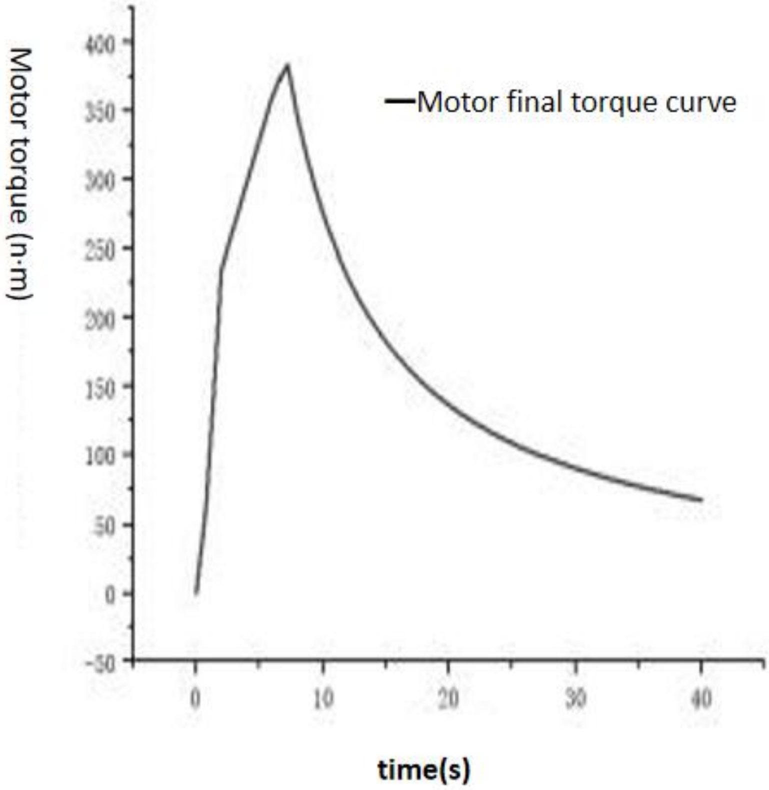

Fig. 14. Final motor torque change curve

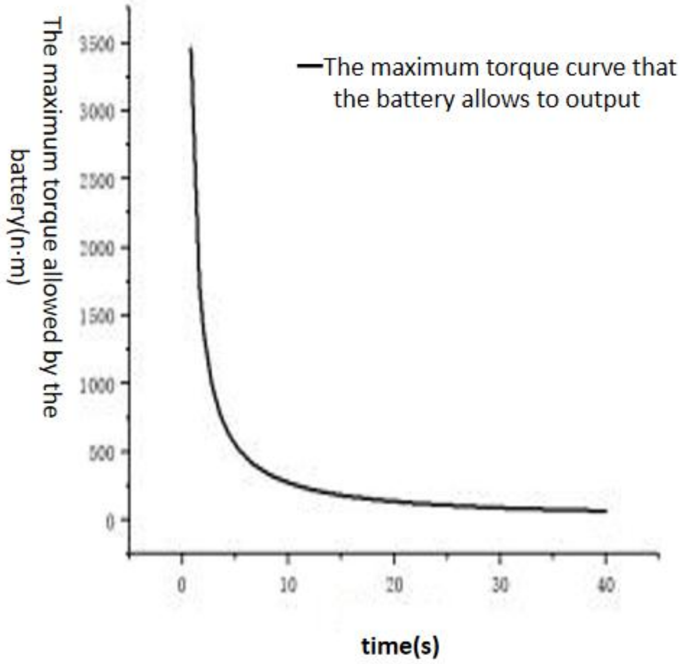

Fig. 15. Maximum output torque allowed by the battery

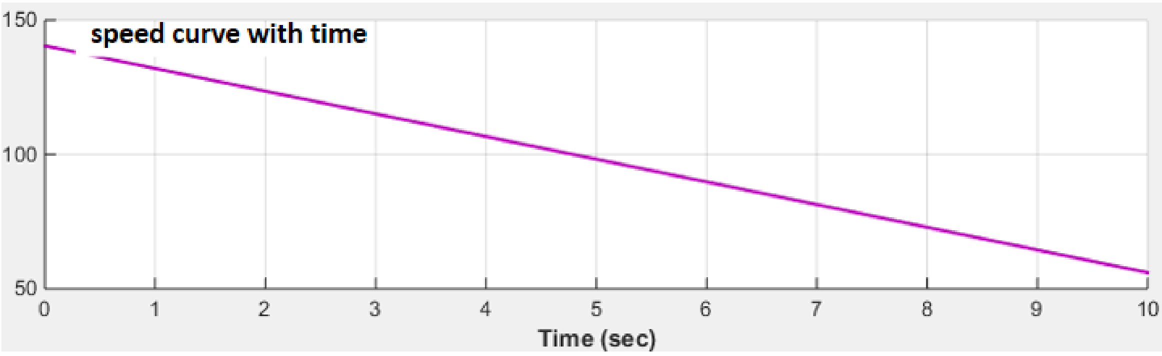

Fig. 16. Simulation signal of speed curve over time

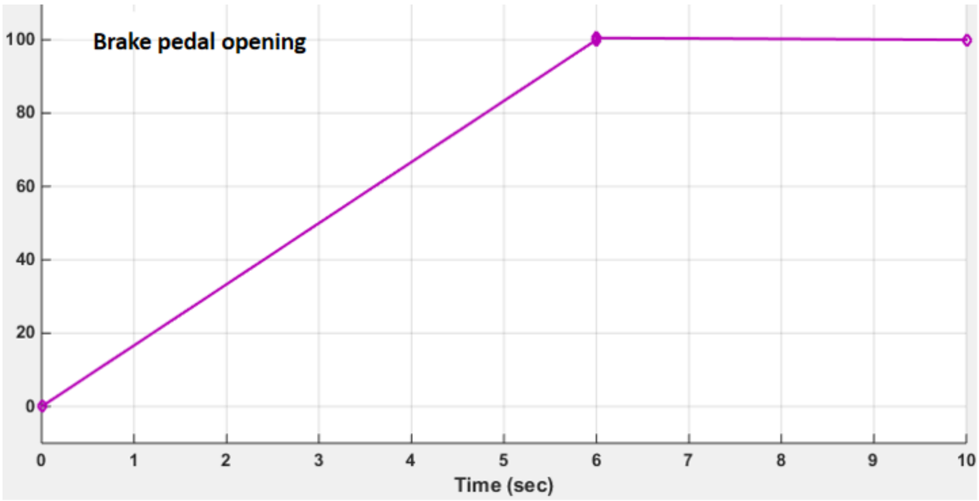

Fig. 17. Brake pedal curve with time Simulation signal

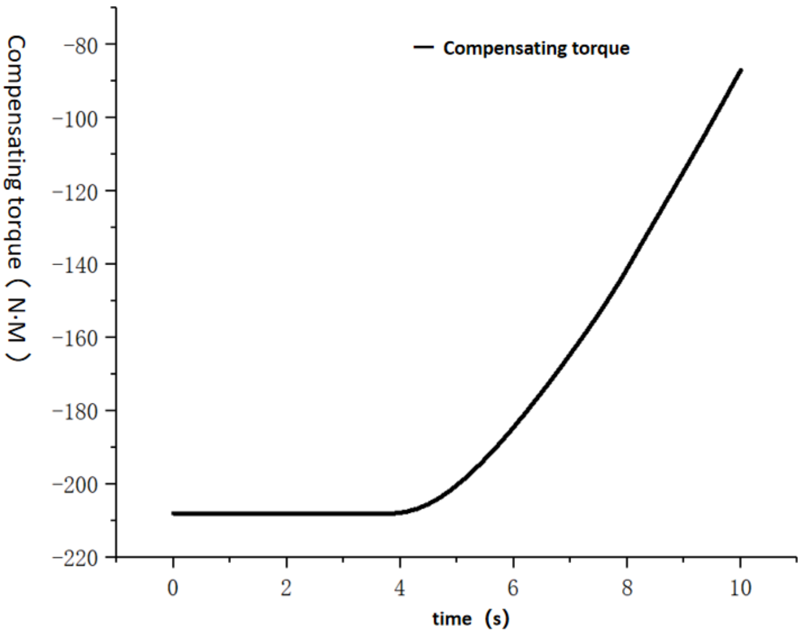

Fig. 18. Compensation torque curve over time

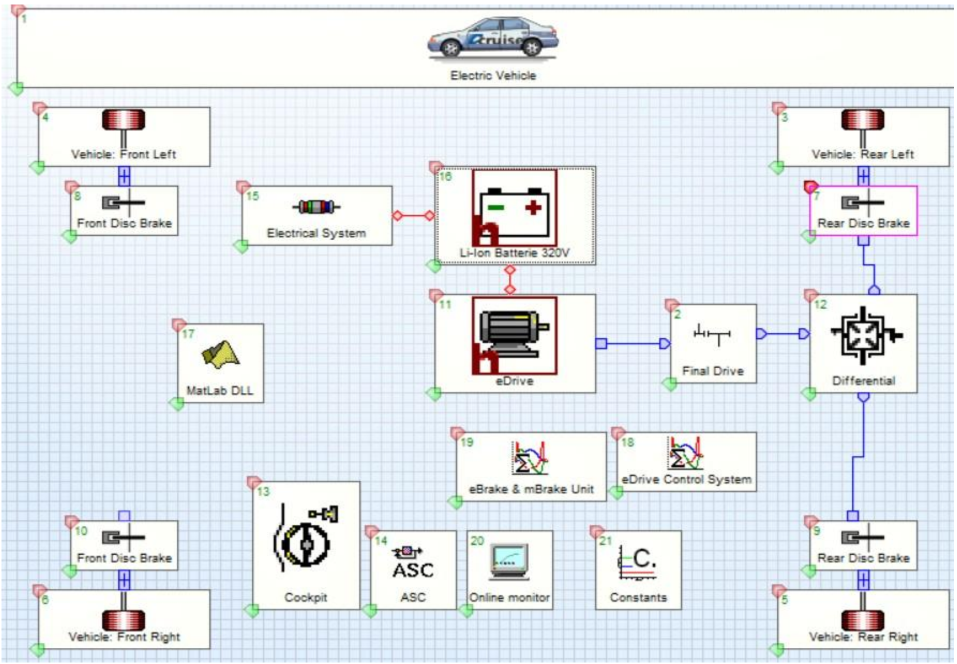

Fig. 19. pure electric vehicle Simulation model

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].

4.2 CRUISE Vehicle Module Parameter Setting

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

4.3 The Drive Control Strategy Simulink Model is Integrated With the Whole Vehicle CRUISE Model

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

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

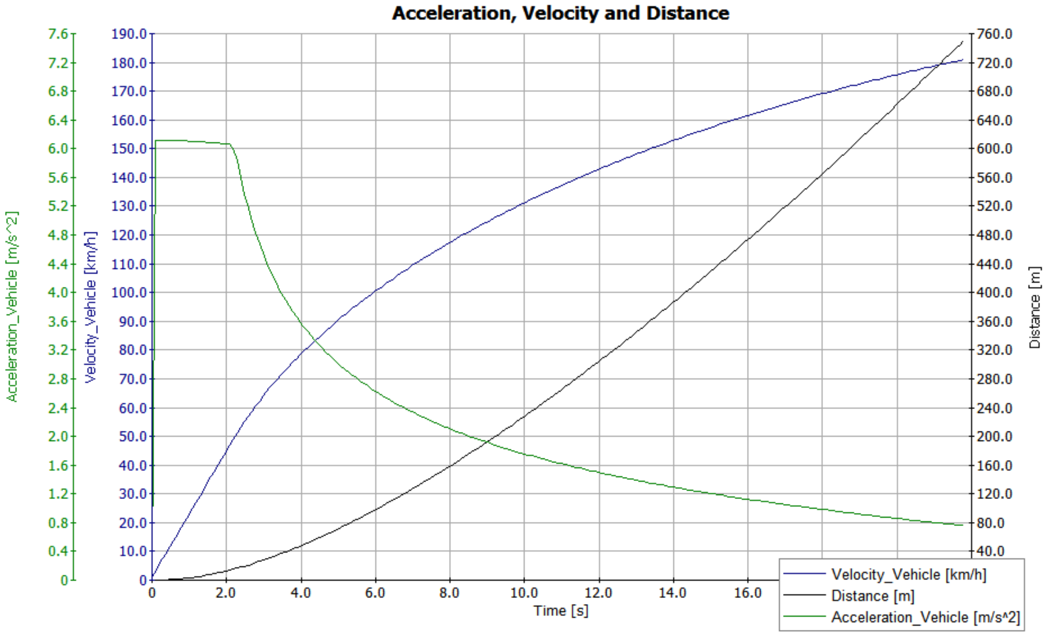

Fig. 20. Acceleration, speed, and distance curve

Measuring Points VELOCITY

Velocity <km/h>	Gear <->	Time <s>	Distance <m>	Speed <1/min>	Measured Speed Ratio <->
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

Fig. 21. Acceleration performance from 0 to 100km/h with the control policy

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

5. CONCLUSION

The whole vehicle control strategy of pure electric passenger car is designed in MATLAB/simulink. The driving control strategy and the control strategy modeling and Simulation of braking energy recovery mode are analyzed in detail. The model of pure electric passenger car was built in AVL CRUISE software, and parameters were set for modules such as pure electric passenger car, drive motor, power battery, and automobile tire. After that, all modules were connected, including physical connection and electrical connection between modules. The most important step before co-Simulation is as follows: That's the signal connection. In AVL CRUISE software, the drive control strategy of the pure electric passenger car designed in advance is imported into MATLAB/simulink software, and AVL CRUISE software makes a joint analysis to analyze the economic and dynamic performance of the pure electric passenger car through the set calculation tasks. It is concluded that the drive control strategy of pure electric passenger car has its unique practicability and superiority.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Suh IS, Lee MY, Vu DD. Prototype design and evaluation of an FSAE-based pure electric vehicle with wireless charging technology [J]. International Journal of Automotive Technology. 2014;15(7):1165-1174.
2. Shen Zhao, Zhou Fuliang, Mao Jianguo, Chen Wei, Yan Zhiwei. Research on rapid integration of drive control strategy for pure electric vehicles [J].Journal of Chongqing University of Technology (Natural Science). 2023;37(05):12-18.
3. Bailey PD. Modelling future vehicle exhaust emissions in Europe [J]. Water Air & Soil Pollution. 1995;85(4):1879-1884.
4. Zhao Jinbao. Pure electric car sanitation vehicle control strategy [J]. Journal of Practical Technology. 2022;47(22):11-15. DOI:10.16638/j.carolcarrollnki.1671-7988.2022.022.003
5. Zhao Shuang, Su Songlin, Wu Aoxue. A pure electric vehicles from the learning control strategy [J]. Journal of Practical Technology. 2023(6):13:22-26. DOI:10.16638/j.carolcarrollnki.1671-7988.2023.06.005.
6. Xu Yang, Zhou Kui, Yang Yahui, Yang Qian, Fu Yongzhi. Research on regenerative braking energy distribution strategy of in-wheel driven electric vehicle [J]. Journal of Chongqing University of Technology (Natural Science). 2023; 37(02):68-76.
7. Liu Yongshan. Research on Controller Development and Control Strategy of Pure Electric Vehicle [D]. Wuhan University of Technology; 2014.
8. Wan Haitong. Research on Drive Control Strategy of Pure Electric Vehicle [D]. Beijing Institute of Technology; 2016.
9. Wang Wei qiang, Yu Tianci,Yan Yunbing.Research on energy recovery strategy of reg-enerative braking of electric bus[J]. Mechanical Design and Manufacturing.2023(02):127-131. DOI:10.19356/j.cnki.1001-3997.2023.02.004
10. Yang Shen. Research on Integrated Control Method for Yaw Stability of Electric Vehicle Driven by Hub Motor [D]. Chongqing University of Technology; 2017.
11. Pan Lei. Research on Power System Matching and Simulation Optimization of Pure Electric Vehicle [D]. Chang 'an University; 2015.
12. Chang Zhichao. Research on Control Strategy of Pure Electric Vehicle [D]. Chang 'an University; 2017.
13. Liu Yang, Hu Jialei. Hybrid electric vehicle energy management system control

strategy study [J]. Journal of Information Technology. 2016;9:121-125+129. DOI:10.13274/j.carolcarrollnkiHDZJ. 2016.09.032

14. Lin Xinyan, Ruhai GE, Wang Bin, et al. Research on parameter matching and simulation of power system of pure electric vehicle [J]. Machine Building. 2014;52(8): 6-10.
15. Zhang Yu. Research on regenerative braking control strategy of hybrid electric vehicle [D]. Harbin University of Science and Technology; 2010.
16. Liu Fuxiao, Zhao Han, Jiang Hao. Research on shift rule and simulation of pure electric vehicle AMT [J]. Journal of Hefei University of Technology (Natural Science Edition). 2013(11):1281-1284.
17. Yu Zhisheng. Automobile Theory [M]. Beijing: China Machine Press. 1982;1-68.
18. Luo Shi, Zhang Dandan, Zhu Changshun, et al. Starting simulation of pure electric bus [J]. Mechanical and Electrical Engineering. 2015;32(1):141-145.
19. Yin Pengfei. Design and simulation analysis of two-speed automatic transmission for electric vehicles [D]. Harbin Institute of Technology; 2015.
20. Du Xuejing, Wang Ning, Cui Shuhua. Research on control strategy of extended range electric vehicle based on fuzzy logic algorithm [J]. Journal of Highway and Transportation Science and Technology. 202;39(12):213-223.
21. LI Zhaomin. Research on braking control strategy of electric vehicle [J]. Times Automobile. 2019(11):58-59.
22. Dong Wei. Pure electric vehicle control strategy study [J]. Modern manufacturing technology and equipment. 2018;7:51 and 53. DOI:10.16107/j.carolcarrollnkimmte. 2018.0603
23. He Kun, Zhang Bin. Analysis and Research of Electric Vehicle Drive Motor Control Strategy [J]. Southern Agricultural Machinery. 2023;54(13):28-31.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/102341