International Journal of Engineering Innovation & Research
Volume 10, Issue 3, ISSN: 2277 – 5668

Parameter Matching and Modeling Simulation Analysis of Extended Range Electric Vehicle

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Date of publication (dd/mm/yyyy): 26/05/2021

Abstract **– In this paper, the parameters of the main power components of the extended range electric vehicle are matched, and the rule-based logic threshold energy management control strategy is formulated. The model is established through the virtual simulation platform to verify its effectiveness. Firstly, the parameters of the main power components are matched according to the vehicle performance index. Secondly, the rule-based energy management control strategy is formulated. Then, the whole vehicle model is established based on MATLAB/ Simulink. Finally, the correctness of the vehicle model and energy management control strategy is verified by running in NEDC (New European Driving Cycle) standard cycle conditions and Zibo City road conditions. The simulation results show that the parameters matching of the extended range electric vehicle is reasonable, which can meet the dynamic and economic requirements under various conditions.**

Keywords **– Extended Range Electric Vehicles, Parameter Matching, Energy Management Control Strategy, Simulation Analysis.**

I. Introduction

With the shortage of fossil energy and the aggravation of environmental pollution, the commercialization of new energy vehicles is particularly important [1]-[3]. Pure electric vehicle as the future target vehicle, because the battery technology is still in the bottleneck period at this stage, it makes the pure electric vehicle unable to realize the commercialization and industrialization at this stage because of the lack of driving range [4]-[5]. As the most ideal transition vehicle, extended range electric vehicle adds a range extender composed of engine and generator on the basis of pure electric vehicle, which not only extends the driving range, but also continues the advantages of low emission and low pollution of pure electric vehicle [6]-[7]. Firstly, the parameters of battery, range extender and drive motor are matched according to the vehicle dynamic performance index. Secondly, the rule-based logic threshold energy management control strategy is formulated. Then the vehicle dynamic model is established based on MATLAB/Simulink. Finally, based on MATLAB/Simulink platform, the simulation analysis of NEDC standard cycle condition and Zibo City road condition is carried out to verify the correctness of the model and control strategy.

II. Power System of Extended Range Electric Vehicle

The overall power system of extended range electric vehicle is shown in Fig. 1. Extended range electric vehicle is mainly composed of range extender, power battery, driving motor and drive system [8]-[9]. As the only power source of the whole vehicle, the driving motor is mechanically connected with the drive system to drive the whole vehicle [10]-[11]. As the power source of the whole vehicle, the power battery provides energy for the whole vehicle when the SOC (State of Charge) is sufficient. As an auxiliary energy source, the range extender provides energy for the whole vehicle when the output power of the power battery is insufficient or the demand power of the whole vehicle is too high [12]-[13]. The generator in the range extender is mechanically connected with the engine. Because there is no direct connection between the engine and the drive system, its working range is extremely flexible, which can effectively improve the fuel economy of the whole vehicle [14].

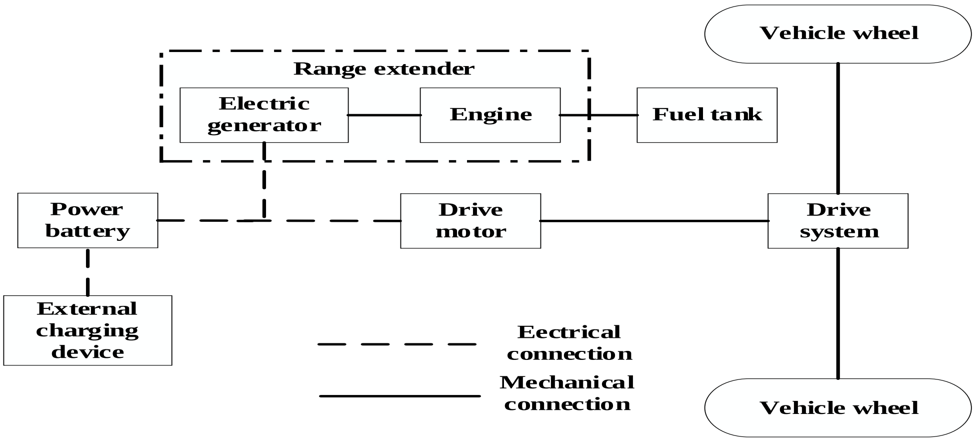


Fig. 1. Power system structure diagram of extended range electric vehicle.

This paper takes an extended range electric vehicle as the research object, and its basic parameters are shown in Table 1.

Table 1. Vehicle parameters and performance indexes parameters.

	Parameter Name	Parameter Value
Vehicle parameters	Curb weight [m/kg]	1250
	Wheel radius [r/m]	0.301
	Single stage final drive ratio [β]	5.5
Performance index	Maximum speed [v_{max}/km•h^{-1}]	≥150
	0~100km/h acceleration time [t_m/s]	≤10
	30km/h maximum climbing gradient [i_{max}/%]	≥30

A. *Matching of Driving Motor Parameters*

(a) *Peak Power Calculation*

In order to ensure that the drive motor can meet the dynamic performance of the whole vehicle, it is necessary to determine the maximum power of the driving motor according to the maximum vehicle speed, acceleration performance and maximum gradient, as shown in the following formula.

$$p_{max\,1} = \frac{u_{max}}{3600\eta_t}\left(mgf + \frac{C_d A u^2{}_{max}}{21.15}\right) \tag{1}$$

$$p_{max\,2} = \frac{u}{3600\eta_t t}\left(\delta m \frac{u}{2\sqrt{t}} + \frac{mgft}{1.5} + \frac{C_d A u^2 t}{21.15 \times 2.5}\right) \tag{2}$$

$$p_{max\,3} = \frac{u}{3600\eta_t}\left(mgf\cos\alpha + mg\sin\alpha + \frac{C_d A u^2}{21.15}\right) \tag{3}$$

Calculated P_{max1} = 43.76kW, P_{max2} = 102.04kW, P_{max3} = 33.61kW, Finally take P_{max} = 110kW.

(b) *Rated Power of Motor*

The relationship between the rated power and the peak power of the motor is as follows.

$$P_{ratd} \geq \frac{P_{peak}}{\lambda} \tag{4}$$

λ is the overload factor, take 2~3. Taking 2.39 this time, the rated power of the motor is 46kW.

B. *Power Battery Matching*

The driving energy of extended range electric vehicles mainly comes from the power battery, but at present, the power battery has some problems, such as high price, large volume, large mass and so on. Therefore, it is necessary to carry out reasonable parameter matching according to the requirements of vehicle power performance and driving motor parameters. In order to meet the performance requirements of the drive motor, the energy, power and capacity of the power battery are matched as follows.

$$E_B \geq \frac{mgf + C_D A v_a^2 / 21.15}{3600 \times DOD \eta_t \eta_m \eta_{bat} (1 - \eta_a)} \times S_{ev} \tag{5}$$

$$P_{bat\,max} \geq \frac{P_{max}}{\eta_m} + P_A \tag{6}$$

$$C_E = 1000 E_B / U_E \tag{7}$$

$$C_P = 1000 * P_{bat\,max} / k / U_E \tag{8}$$

The main parameters of the power battery calculated by the above formula are shown in Table 2.

Table 2. Main parameters of power battery.

Parameter Name	Value
Cell voltage[V]	3.2
Number of monomer	120
Rated voltage[V]	384
Capacity[Ah]	45
SOC scope[%]	20~100

C. *Range Extender Matching*

(a) *Engine Matching*

When the power battery is insufficient, the engine needs to meet the power requirements of the vehicle when driving. When matching engine parameters, not only need to consider whether its output power meets the requirements of generation, but also should make the high efficiency range of generator and engine the same as far as possible. The engine power matching is shown in the following formula.

$$P_{req} = \frac{v}{3600\eta_t\eta_m\eta_g}\left(mgf + \frac{C_D A v^2}{21.15}\right) + \frac{\Delta p}{\eta_g} \quad (9)$$

The output power of the selected engine in the high efficiency zone is 18~25kW, the corresponding speed is 2300~4400r/min, and the maximum power is 50kW. The maximum torque is 100Nm, and the final selected engine parameters are shown in Table 3.

Table 3. Engine parameters.

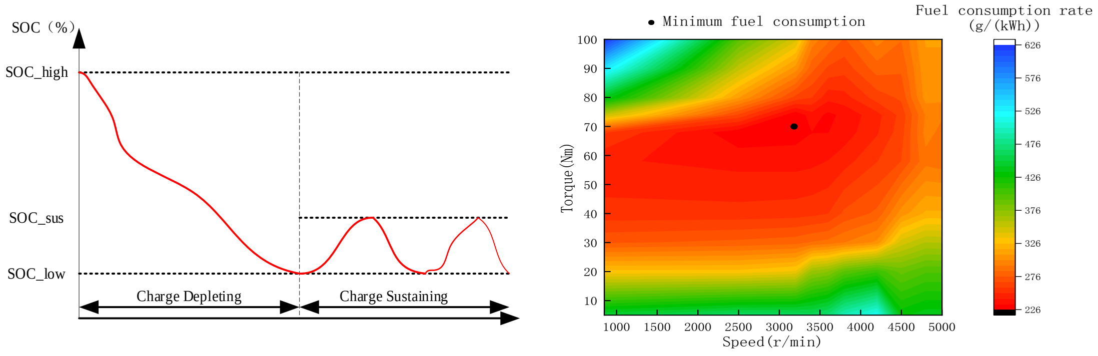
Parameter	Value	Parameter	Value
Peak speed [r/min]	5000	Rated speed [r/min]	3200
Peak power [kW]	50	Rated power [kW]	25
Peak torque [Nm]	100	Rated torque [Nm]	70

(b) *Generator Matching*

Because the engine and generator are connected in the axial way in the range extender, it should be followed when matching the parameters of generator. The rated power, speed range and working efficiency area of generator should be basically the same as the rated power, speed range and working efficiency area of the generator.

III. ENERGY MANAGEMENT STRATEGY OF EXTENDED RANGE ELECTRIC VEHICLE

At present, rule-based energy management strategy is mainly used in extended range electric vehicles, including single point constant temperature control strategy and power following control strategy [15]. Single point constant temperature control strategy means that the range extender outputs a constant power and is not affected by the driving conditions of the whole vehicle. The power following strategy can adjust the output power of range extender to follow the real-time and accurate change of vehicle demand power. Due to the indirect mechanical connection between the engine and the drive motor of extended range electric vehicle, in order to improve the fuel economy of the whole vehicle, this paper adopts a single point constant temperature control strategy. When SOC is lower than the set lower limit, the range extender is on. When SOC is higher than the upper limit value, the range extender is closed. In this interval, the last state is maintained. Schematic diagram of single point constant temperature control strategy and the selection of engine working point are shown in the Fig. 2.



(a) Schematic diagram. (b) Engine working point.

Fig. 2. Single point constant temperature control strategy.

IV. Verification Analysis of Simulation Results

A. *Simulation Analysis of Vehicle Model under NEDC Condition*

The matching vehicle simulation model is established by MATLAB/Simulink platform as shown in Fig. 3. The simulation results of the vehicle running 4 NEDC conditions are shown in Fig. 4. Fig. 4 (a) (b) are the local NEDC cycle diagram of 4 NEDC cycles.

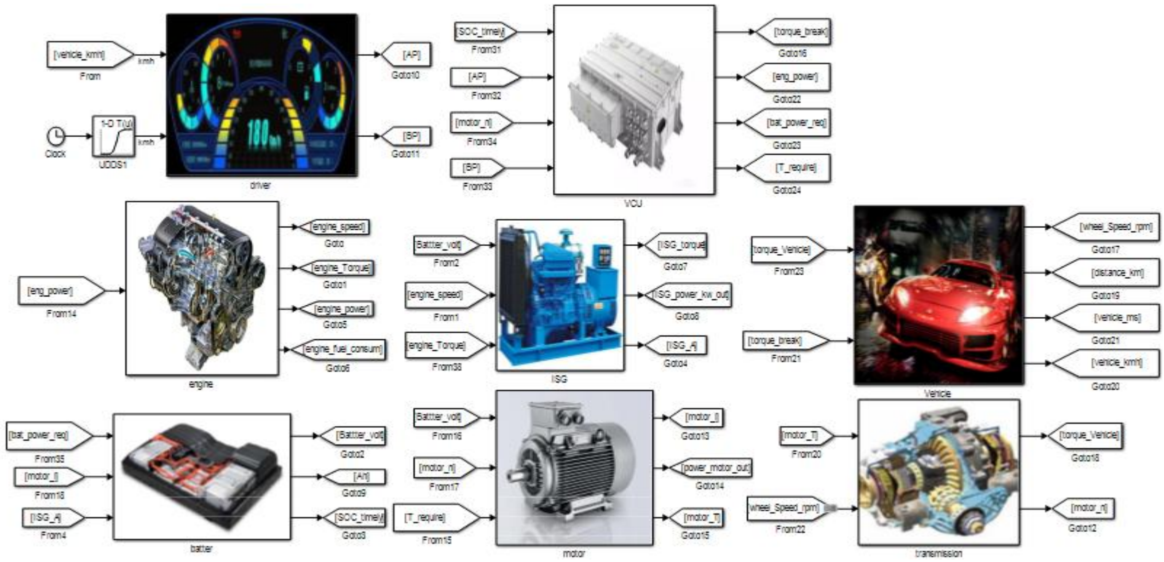
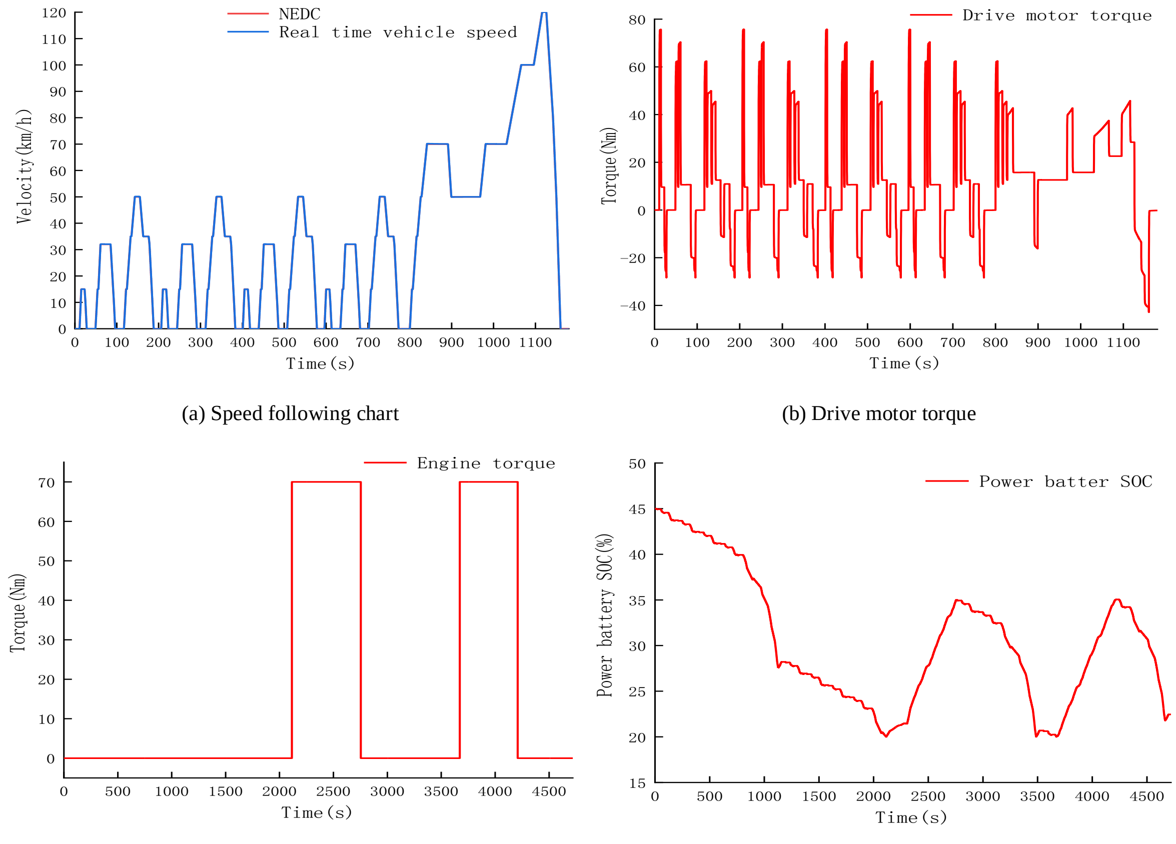


Fig. 3. Extended range vehicle dynamics model.



(a) Speed following chart

(b) Drive motor torque

(c) Engine torque

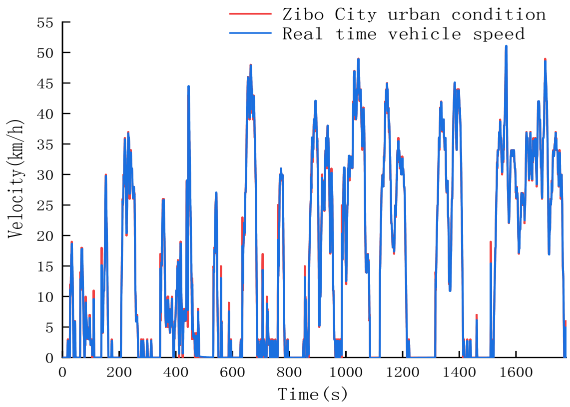
(d) Power battery SOC

Fig. 4. Simulation result chart of NEDC.

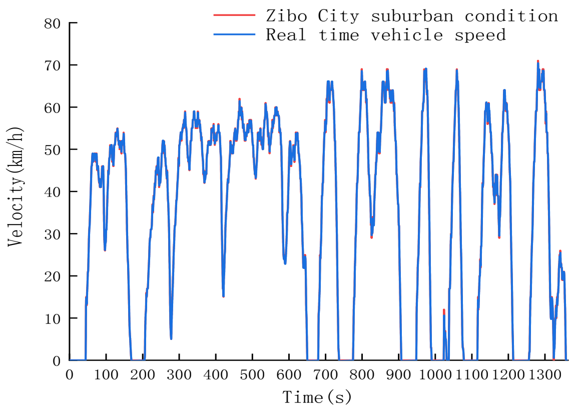
It can be seen from the simulation results in Fig. 4 (a) (b) that the extended range electric vehicle can well follow the NEDC cycle conditions. Fig. 4 (c) (d) shows that the energy management strategy of single point constant temperature control of the whole vehicle can ensure that the engine can start when SOC = 20%, stably working torque is 70Nm and providing energy for the whole vehicle and power battery. Engine can turn off when SOC = 35% and turn on pure electric mode. By opening and closing the range extender, the driving range of extended range electric vehicle can be effectively extended and the vehicle economy can be improved.

B. *Simulation Analysis of Vehicle Model of Zibo City Suburban Road Condition*

The collected data of Zibo City road speed is input into Simulink module. The simulation results based on MATLAB/Simulink platform are shown in Fig. 5.



(a) Urban condition



(b) Suburban condition

Fig. 5. Simulation result chart of Zibo City.

It can be seen from Fig. 5. that compared with NEDC standard cycle condition, the speed of Zibo City condition measured by real vehicle changes rapidly. But the establish extended range electric vehicle model can still accurately and rapidly follow the speed change, which can effectively verify the correctness of the established vehicle dynamics model.

V. Conclusion

In this paper, based on the V-shape development process of the vehicle, the parameters of the main power components of the vehicle are matched according to the vehicle dynamic performance index. The forward and backward modeling method is used to establish the dynamic model of the extended range electric vehicle, and the energy management strategy based on single point constant temperature control is formulated. Finally, the simulation analysis of NEDC standard cycle condition and Zibo City road condition based on MATLAB/ Simulink platform shows that the model can follow the established working conditions effectively, and the energy management control strategy can also ensure the economy of the whole vehicle.

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