Research on New Energy Vehicle Intelligent Control Kinetic Energy Recovery Technology

Mingyu Lu

Anhui Sanlian University, KLAHEI18018, Traffic Engineering College, He Fei, An Hui, 230601, China
jtlumingyu@126.com

Abstract

In order to maintain battery life and improve energy utilization. By analyzing the energy loss during the driving of new energy vehicles, the energy recovery technology of vehicle intelligent control is studied. Based on Internet technology, battery state of charge and vehicle speed, research the impact on intelligent recovery, analyze the relationship between front and rear braking forces, and the relationship between braking intensity and braking torque, according to the relationship between the braking torque required by the computer control, Based on the establishment of an intelligent control model, the simulation environment is used to conduct experiments. The results show that the proposed intelligent control system can effectively improve the braking energy recovery rate.

Keywords: *Intelligent control, Internet, Simulation*

1. INTRODUCTION

With the intensification of the energy crisis, the global energy panic, coupled with environmental protection factors, electric vehicles have attracted people's attention, but their endurance limits their development speed. Therefore, the research on the battery life of electric vehicles is an important problem that needs to be solved urgently [1]. Studies have shown that the energy recovery of electric vehicles can effectively improve their endurance [2]. For the development of electric vehicles, energy recovery is the most urgent problem that needs to be solved at present. Braking energy refers to the mechanical energy that has been output when the car is braking; recovery refers to the energy storage that converts the mechanical energy when the car is running into other forms (mainly electrical energy storage [3]: that is, stored in the battery through the motor). up for further conversion. Therefore, the braking energy recovery of electric vehicles is the conversion of mechanical energy and electrical energy through the reversal of the motor when the driver brakes the vehicle, and the reversal of the distributed motor to stably decelerate or stop the vehicle. At the same time, the energy conversion of the motor reverses. Charge the battery to a state of battery charge to increase its battery life. Studies have shown [4] that the battery life of electric vehicles can be improved by 10% to 30% through energy braking recovery.

At present, some scholars have made corresponding research on energy recovery. Chen Zan et al. [5] studied the recovery of braking energy from the perspective of vehicle speed and battery state of charge. This study ignores the influence of braking intensity. It is not conducive to the recovery of braking energy. Chang Jiujian et al [6] started with the braking intensity and studied the influence of different braking systems on the energy recovery rate, and concluded that the electromechanical braking system not only responds quickly, but also recovers a relatively large amount of braking energy, but this study only considers The braking intensity variable is relatively single, which is not conducive to comprehensive evaluation. Chen Yong [7] and others studied the influence of motor recovery torque on battery power and vehicle cruising range, and concluded that under frequent braking conditions, energy recovery is greater, but the impact of vehicle speed was not increased during the research process.

In order to further study the problem of braking energy recovery rate, this paper studies the energy recovery of electric vehicles based on distributed braking system. Therefore, the braking strategy is designed. Through the research, the energy recovery effect of the distributed line control system during braking is analyzed and discussed.

A. El-Hashash et al. (Eds.): IEIT 2022, ACSR 100, pp. 1015–1020, 2023.
https://doi.org/10.2991/978-94-6463-058-9_159

2. DESIGN OF DISTRIBUTED BRAKE-BY-WIRE SYSTEM

2.1. Distributed braking system works

The distributed brake-by-wire system is different from the traditional braking system, relying on wires, identifiers, and controllers to transmit signals and convert energy [9], and mainly rely on the upper and lower controllers to transmit braking signals [10].

In the braking system, the brake pedal transmits the braking signal to the sensor, the sensor transmits the braking information to the controller, the controller transmits the calculated braking force to the upper controller, and the upper controller identifies the braking intensity and brakes. The selection of the mode transmits the processed information to the lower brake, and the lower brake uses the braking strategy to distribute the braking force to achieve the braking effect.

2.2. Regenerative braking force distribution design

When the lower-level controller processes the braking intensity information, in order to ensure the stability of the braking, the braking force of each wheel is distributed according to the braking force distribution curve of the car(Ye2013). Such as (1):

$$\begin{cases} F_1 = \frac{G}{L}(b + \varphi h) \\ F_2 = \frac{G}{L}(a - \varphi h) \end{cases} \tag{1}$$

in the formula:

F_1——Front axle normal reaction force（N）；

F_2——Rear Axle Normal Reaction（N）；

G ——Vehicle gravity（N）； L ——Front and rear wheelbase（m）；

a ——Front axle to centroid distance（m）； b ——Rear axle to centroid distance（m）；

φ ——The utilization adhesion coefficient of the car; h ——high centroid（m）；

In the current state of rear wheel locking, its expression is as follows（2）：

$$\begin{cases} F_3 + F_4 = \varphi G = \frac{T_1}{R} \\ F_3 = \varphi F_1 \\ F_4 = \varphi F_2 \end{cases} \tag{2}$$

in the formula:

F_3——Front axle braking force（N）； F_4——rear axle braking force（N）；

T_1——Braking torque（N·m）； R——wheel radius（m）.

The relationship between F_4 and F_3 can be obtained by arranging the above formula, such as（3）：

$$F_4 = \frac{1}{2}\left[\frac{G}{h}\sqrt{b^2 + \frac{4hL}{G}F_3} - \left(\frac{G}{b} + 2F_3\right)\right] \tag{3}$$

The relationship between the braking torque T_1 and the front and rear braking forces is as follows（4）：

$$T_1 = (F_3 + F_4)R \tag{4}$$

And the relationship between the braking intensity Z and T_1 braking torque, the relationship is as follows（5）:

$$Z = \frac{T_1}{GR} \tag{5}$$

Combining formulas (3) (4) and (5), it can be seen that during the braking process of the vehicle, the braking strength changes with the front and rear braking forces. In order to ensure the safety in the braking process, combined with the ECE R13 braking regulations formulated by the United Nations, the front and rear braking forces are distributed during braking. Combined with the calculation, this paper takes the front and rear brake distribution coefficient as 0.6.

3. RESEARCH ON BRAKING ENERGY RECOVERY

3.1. Motor model establishment

As can be seen from Figure 1, in the entire process of online control of kinetic energy recovery, the motor is one of the most core components in energy conversion. The difference between the forward and reverse rotation will determine whether the motor is driven energy output or braking energy recovery, and the effect of braking energy recovery. Therefore, the analysis of the motor is very important.

Whether in the process of driving or braking, the power of the motor determines the driving energy consumption and the recovery effect of braking energy. Therefore, when analyzing the energy recovery of the vehicle, the power of the motor is used to analyze the recovery of the regenerative braking energy during the braking process. So as to obtain the factors that affect the energy recovery.

The voltage, resistance, and speed determine the recovery power of the motor, and its expression is as follows（6）：

$$P = -\frac{1}{R}U^2 + \frac{K_1 n}{R}U \tag{6}$$

In the formula：

P——Motor Power（W）； R——Equivalent resistance（Ω）；

U——Charging voltage（W）； K_1——Back EMF coefficient；

n——Motor speed（r/s）.

From the definition of power, the braking energy can be calculated by the superposition of braking power and time, such as (7)）：

$$E = \int_0^T P\,dt \tag{7}$$

Substitute equation (6) into (7) to get：

$$E = \int_0^T \left(-\frac{1}{R}U^2 + \frac{K_1 n}{R}U\right) dt \tag{8}$$

By the motor speed expression, such as (9)：

$$\begin{cases} n = \frac{v(1-s)}{r} \\ v = v_0 - Zgt \end{cases} \tag{9}$$

In the formula：

v——braking speed（m/s）； s——wheel slip；

v_0——brake first speed（m/s）； r——wheel radius（m）

From equation (6), it can be known that when $U = \frac{K_1 n}{2}$, the braking power reaches the maximum，Integrating $U = \frac{K_1 n}{2}$ with equations (6) (8) (9) can get (10) as follows：

$$\begin{cases} P_{max} = \frac{K_1^2}{4R}\left[\frac{v_0 - Zgt}{r}\frac{1-S}{r}\right]^2 \\ E = \int_0^T \frac{K_1^2}{4Rr^2}(v_0 - Zgt)^2(1-s)^2\,dt \end{cases} \tag{10}$$

The time it takes for the car to brake at the initial speed v_0 to the end of braking can be obtained from Equation (9), $T = \frac{v_0}{Zg}$，which is substituted into Equation (10) to get Equation (11) as follows：

$$E = \frac{K_1^2}{4Rr^2}(1-s)^2\frac{v_0^3}{3Zg} \tag{11}$$

It can be seen that in the process of braking, the effect of energy recovery is related to the vehicle type (K_1 back EMF coefficient, r wheel radius, R equivalent resistance), working conditions (s wheel slip rate), v_0 initial braking speed, Z braking intensity. Among them, when the research direction is determined, the model and working conditions have been basically determined, that is, K_1、r、R and s are already quantitative, so the amount of braking energy recovery is related to the initial braking speed, braking intensity and other factors, so The analysis is performed in the lower level controller study.

3.2. Battery model

When studying the energy recovery of the electric vehicle braking system, the battery is discharging or charging indiscriminately whether the vehicle is driving or braking. However, studies have found that [9, 10], when the capacity of the battery (replaced by SOC below) is, the battery provides a stable working voltage, and this stage is the most suitable for charging the battery and is also the most suitable stage for braking energy recovery; when When $SOC > 90\%$ or $SOC < 10\%$, due to the unstable voltage, in order to protect the service life of the battery and increase the battery life, it is not suitable to charge and discharge the battery, so the lower brake at this stage should be controlled by the energy recovery system.

3.3. Control strategy design

From the above research, it is known that the recovery of braking energy is affected by the braking intensity, the initial braking speed, and the battery. It can be known from equations (4) and (5) that the braking intensity changes with the change of the front and rear braking forces. Reference shows that: for a car, the braking strength should be taken, and the recovery of braking energy should be carried out. At the same time, when the initial braking speed $> 5\text{km/h}$, the proportion of braking energy recovery increases. In this paper, the braking strategy is designed, the flow chart is shown in Figure 1.

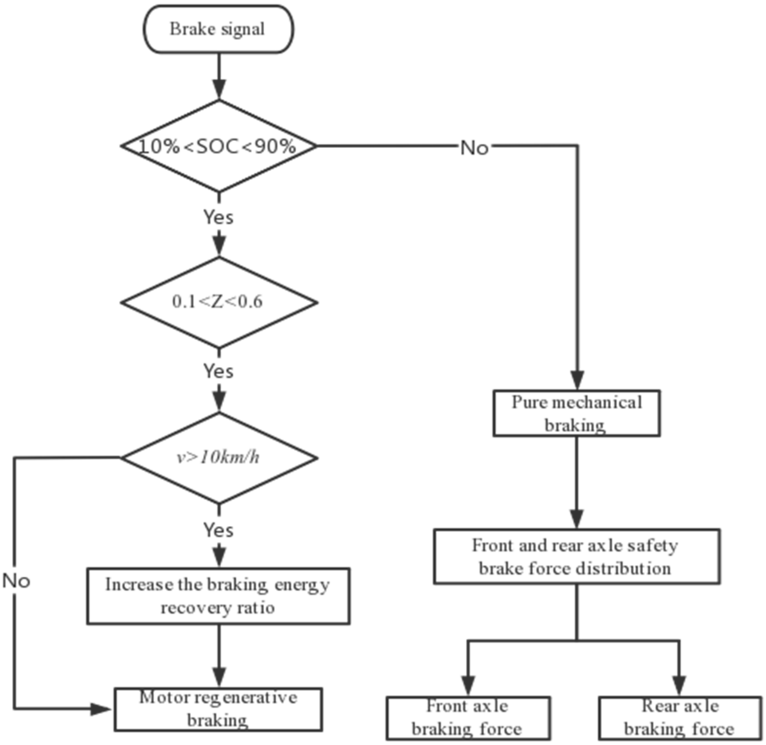

Figure 1 Flow chart of braking control energy recovery

4. SIMULATION ANALYSIS

4.1. Simulation build

In order to verify the effect of the control strategy of the distributed control-by-wire energy recovery system, Simulink and CarSim are used for simulation. Without considering the loss of energy during the transmission by wire, a comparative experiment is carried out on the energy recovery strategy of the distributed fuzzy control system and the improved control strategy, and simulation experiments are carried out under different road conditions. The vehicle model parameters are shown in Table 1.

Table 1 Car model parameters

Parameter	value
Vehicle quality(kg)	790
High centroid(m)	0.5
Wheelbase(m)	2.71
Front axle to centroid distance(m)	1.36
Rear axle to centroid distance(m)	1.35
Tire rolling radius(m)	0.32
Motor speed(r/min)	600
Motor rated voltage(V)	72
Motor rated/peak torque(N*m)	57/120
Motor rated/peak power(kw)	3.4/7
Battery rated capacity(Ah)	160
Battery rated voltage(V)	72

4.2. Analysis of simulation results

Control experiments were carried out under ECE, CLTC-P, and NEDC conditions, and their dynamic changes are shown in Figures 2, 3, and 4 below.

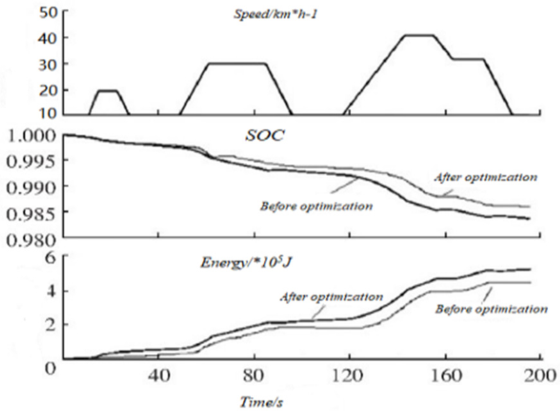

Figure 2 Comparison of simulation changes under ECE conditions

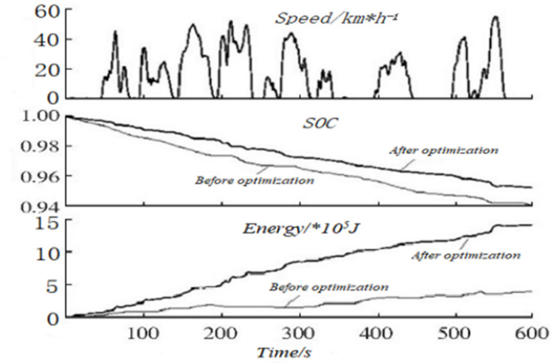

Figure 3 Comparison of simulation changes under CLTC-P condition

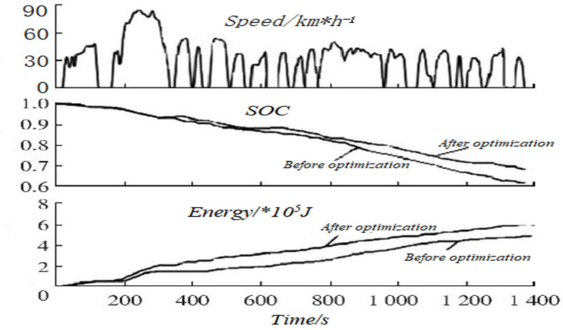

Figure 4 Comparison of simulation changes under NEDC conditions

According to the experimental results in the figure, under the condition of motion cycle, with the change of speed, the trend of its energy can be known：

Under the ECE condition, at 57 s , both the pre-optimization and post-optimization schemes are improving energy recovery, but after 131s, the energy recovery rate after optimization is better than that before optimization. At the end of energy recovery, the optimized energy storage is 5.16×10^5J, 4.32×10^5J before optimization.

Under the CLTC-P working condition, at 69s, the schemes before and after the optimization are improving the energy recovery. At the end of the energy recovery, the energy storage after optimization is 13.43×10^5J, and the energy storage before optimization is 4.17×10^5J.

In the NEDC working condition, at 200 s , the solutions before and after the optimization are improving the energy recovery. At the end of the energy recovery, the energy storage after optimization is 5.85×10^5J, and the energy storage before optimization is 4.30×10^5J.

According to the designed control system, after the braking reaction time, no matter what road conditions can promote the effect of braking energy recovery.

5. CONCLUSION

This paper studies the influencing factors of braking energy recovery, improves the recovery strategy, and conducts simulation experiments. The results show that the improved distributed brake-by-wire system can effectively improve the braking energy recovery rate.

ACKNOWLEDGMENTS

Anhui Sanlian University-Anhui Sanlian Applied Traffic Technology Co.,LtdD Practice education base(2019sjjd61)Research on EPS/ESP control system integration under the design coordination control rules in the "person-vehicle-road" closed-loop system（Grant NO.KJ2020A0797）Research on vehicle brake-by-wire system in intelligent traffic environment （zjt22001）

REFERENCES

[1] Chang Jiujian, Zhang Yufan. Research on optimal control strategy of braking energy recovery for pure electric vehicle based on EMB[J].Automotive Engineering,2022,44(01):64-72.

[2] Chen Yong, Li Congcong, Guo Lishu, Wei Changyin, Qiu Zizhen. Research on energy recovery strategy of pure electric vehicle electro-hydraulic composite braking[J].Journal of Hebei University of Technology,2022,51(01)7-14+20.

[3] Chen Zan, Tan Guangxing, Lin Cong, etc. Braking energy recovery of pure electric vehicles based on fuzzy algorithm[J].Journal of Guangxi University of Science and Technology,2014,25(3):32-37.

[4] Lian Xiaochun, Wu Hu. Principles of Aero Engines[M].Xi'an： Published by Northwestern Polytechnical University,2005.

[5] Li Jun, Li Hulin. A review of state-of-charge estimation methods for electric vehicle lithium-ion batteries[J].Science Technology and Engineering,2022,22(06):2147-2158.

[6] Niu Jigao, Zhang Bing, Xu Chunhua. Research on Braking Energy Recovery of Pure Electric Vehicles Based on Fuzzy Control[J].Journal of Zhongyuan University of Technology,2020,31(02):23-28.

[7] Wu Kailong, Zheng Jianli. Research on braking energy recovery control strategy of new energy vehicles[J].Technology wind,2021,(19):14-15.

[8] Ye Yongzhen, Liu Jiang, Zhou Naitao. Research and Simulation of Braking Energy Recovery Control Strategy for Pure Electric

Vehicles[J].Agricultural Equipment and Vehicle Engineering,2013,51(09):31-34

[9] Zhang Junzhi, Lv Chen, Li Yuzhong. Development status and prospect of electric drive passenger vehicle braking energy recovery technology[J].Automotive Engineering,2014,36(8):911-918.

[10] Zhou Su, Sun Yan, Huang Jing. Research on the influencing factors of electric vehicle braking energy recovery[J].Mechatronics,2019,25(05)10-18.