Study on Intelligent Braking Energy Recovery System

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Abstract. Nowadays, traditional internal combustion engine vehicles use fossil fuels, emitting exhaust gases and pollutants, making a negative impact on air quality and the environment. The intensification of global climate change also makes it particularly important to reduce greenhouse gas emissions. In order to meet the coexistence of the environment and human development, electric vehicles(EV), as a zero-emission transportation mode, can reduce air pollution and carbon emissions, and improve urban air quality. The number of EVs in the world has increased significantly, and the technology of EVs is constantly innovating. In this article, the brake system is extracted separately from the four parts of the traditional EV and treated as the fifth part to work together with the other four parts.This article analyzes the optimization of motor machinery, power recovery and release, and the driver operation and operation safety. In addition, this article also discusses how to effectively alleviate the problems of insufficient power and short battery life of EVs. This article may offer a reference for the development of EVs.

Keywords: Brake System; Wheel Axle; Drive Motor; Electric Vehicle.

1. Introduction

In recent years, electric vehicles (EV) have received growing attention again. Politicians in various countries have recognized EVs as a promising technological alternative to internal combustion engine cars in controlling global warming [1]. Today, the use of EVs is becoming extremely common and even chasing the number of internal combustion engine cars. From the perspective of vehicle combination structure, pure electric vehicles are mainly composed of high voltage electrical system, driving motor system, and low voltage electrical system, power battery system, charging system, chassis system and body. Its high voltage electrical system can be divided into high voltage cable, high voltage accessory cable, slow charging harness, vehicle charger, DC/DC, motor controller system, motor controller, high voltage control box, and fast charging system[2]. So the architecture of a common EV is divided into four key parts: battery system, electric drive system, control unit, and mechanical components. The battery system and control unit can mainly be regarded as the nerve center and energy warehouse of EVs. Electric drive systems are more complex and aim to convert electrical energy into mechanical energy to drive a vehicle forward. The core of the electric drive system is an electric motor transmitting power through the drive shaft. It operates with the support of essential mechanical components. Most of the mechanical components are traditional mechanical components such as chassis, suspension, wheels, and braking systems, as well as parts related to electric characteristics, such as electric drive shafts and drive motors. These components work together to enable EVs to achieve efficient electric drive effects.

Traditional electric vehicle driving and charging systems work independently from each other, which has the problems of small charging capacity, large weight and volume, and high cost [3]. In the face of the current problem of improving the cruise range of EVs, in this paper, the brake system is treated separately as the fifth part and combined with the other four to solve the problems of EVs, such as insufficient power, short range time, and insufficient climbing force. In this paper, the optimized brake system is called the intelligent braking energy recovery system (BERS).

This article will represent the optimization effect. The rationality and operability of the optimized system will be highlighted through the description of the optimization principle and the optimization operation process. The optimal descriptive system is simulated to improve the energy problems of ordinary electric vehicles, and the future market is predicted to help the development of the

optimization system and the driver's guess to get better operating experience through the optimization system.

2. Drive System and Axle System of Traditional EV

To study the development situation evaluation system of electric vehicles, it is necessary to comprehensively consider the development trend of electric vehicles and its related industries, technologies, formats, modes, and markets [4]. It can be found from the data that the transmission efficiency of electric vehicles is much higher than that of fuel vehicles [5].

2.1. Operation Mode of Traditional EV's Driving Motor

The drive motor is one of the core power systems of EVs, which is responsible for converting electrical energy into mechanical energy to drive vehicle motion. The drive motor power system can be divided into several important parts: power supply, inverter, motor control unit, and three-phase asynchronous motor.

An EV's battery pack provides direct current power. These batteries are usually lithium-ion or other types of rechargeable batteries. The electrical energy output from the battery is direct current (DC), while the driving motors of EVs usually need alternating current (AC) to operate. Therefore, an inverter is needed to convert direct current to alternating current. The inverter controls the output AC frequency, voltage and phase according to the working requirements of the driving motor [6]. The motor control unit (MCU) is the computer system of the vehicle, which is responsible for monitoring the vehicle state, the drive requirements and the performance of the drive motor. Based on the information, it controls the inverter to ensure that the motor is getting the proper current and voltage for accurate speed and torque control. This precise control allows EVs to achieve efficient performance in different driving conditions.

2.2. Operation mode of traditional EV axle

The axles of traditional road EVs work differently from those of traditional internal combustion engine vehicles because the power source of EVs is the electric drive system [7]. In some EVs, especially front-drive EVs, a reducer may be used to convert the high speed rotation of the electric drive motor into a torque and speed that is more suitable for vehicle driving. The reducer acts like a transmission in a conventional car, but it is designed more to accommodate the characteristics of EVs. EVs can control their speed and torque output by adjusting the current and voltage of the electric drive motor. The control system of the vehicle can monitor the driving conditions and demands in real time, so as to precisely control the work of the electric drive motor, so that it can provide the right power in different driving situations. EVs can be driven in front, rear or four-wheel drive mode.

3. Definition and Principles of BERS

3.1. Definition of BERS

The BERS system aims to improve the cruise range of EVs and reduce operating costs and environmental impacts by using the energy recovery of braking. This feature uses the energy generated when the brake pedal brakes. The system converts the kinetic energy into electricity and stores the energy in the battery, which is used to drive the EV or provide electricity for other devices.

BERS can monitor the vehicle's speed, acceleration, mileage, and other key data in real time to determine the best timing for energy release. Based on the monitoring data, BERS can automatically control the release of energy to precisely meet the needs of different driving scenarios. When driving at high speed or climbing a hill, BERS can release its own energy storage obtained by braking to provide extra power to the car. When the vehicle is stopped for a long time or has excess power, BERS will release energy in an orderly manner to supply power to the vehicle's electronic equipment. In addition to automatic functions, BERS can also offer manual control options, where drivers can

adjust the timing and speed of energy release according to their own needs. BERS has superior heat dissipation performance and a built-in overload protection system to ensure a safe and reliable energy release process. With the optimized braking system, EVs can make full use of the braking energy during driving to improve the driving range, and at the same time intelligently release the stored energy according to the actual needs. This combination will greatly improve the performance and comfort of EVs.

3.2. Principles of BERS

In the actual three-phase asynchronous motor, the rotating magnetic field is generated by passing symmetric sinusoidal current through the three-phase stator winding [8]. In normal cases, the speed and torque of the electric motor run in the same positive direction. However, each electric motor can also be used as a generator. At this point, the motor continues to rotate in the same direction but is driven by the wheel rather than the other way around. In this case, it does not consume electrical energy but produces it. As it takes a lot of energy to drive an electric motor in order for the rotor to turn under magnetic resistance, this so-called negative torque can be used to slow the vehicle down. When the EV is slowing down or turning at a medium and high speed, the BERS system can control the driving motor to greatly reduce or stop releasing electric energy and at the same time absorb the electric energy generated by the axle and save it in the battery of the system.

In daily driving, the BERS will slow down in most braking cases by electric means. This is based on the inverter ability of the electric drive motor, which can convert the kinetic energy into electricity and store it in the battery. This intelligent energy recovery principle not only minimizes the waste of energy during braking but also improves the energy utilization efficiency of EVs.

However, in some extreme cases, such as driving at maximum speed under full load, the EV drive brake system requires a greater braking capacity to ensure the safety of the vehicle and even has to apply a maximum braking power of more than two megawatts. At this time, the recovery capacity of the electric drive system alone may not be able to meet the braking demand, so the BERS will be more active in combination with the traditional brake, providing additional braking force through mechanical friction braking and the electric energy stored by the system during vehicle inspection. This intelligent hybrid braking system ensures controllable braking of the vehicle at critical moments and provides drivers with safer and more reliable braking performance.

In addition to the extreme case, it is also possible that the battery is fully charged and therefore cannot be recharged through energy recovery. In this case, the "BERS" system intelligently adjusts its strategy to prevent excessive energy recovery and instead converts the braking energy into mechanical braking energy, thus ensuring the performance and lifetime of the battery.

In summary, the BERS plays an important role in both everyday driving and extreme situations through its efficient energy recovery principle. According to the energy loss report of traditional trams, the energy recovery efficiency of BERS up to 290 kW reflects the advanced technology. The application of this technology not only improves the performance and energy utilization efficiency of EVs but also provides a more reliable choice for green travel.

4. Optimization of BERS

BERS utilizes advanced energy conversion technology so that every electric motor can also be used as a generator. At this point, the motor continues to rotate in the same direction, but is driven by the wheel rather than the other way around. As it takes a lot of energy to drive an electric motor in order to turn the rotor against magnetic resistance, this so-called negative torque can be used to slow the vehicle down. In this way, the kinetic energy generated during the braking process is converted into electrical energy when the vehicle brakes, and it is stored in the battery in BERS.

BERS not only improves the braking performance of the vehicle, making the driving safer and smoother, but also enables energy recovery and storage. BERS can intelligently use this stored energy to reduce the extra burden on the battery, thereby improving the range of EVs. In addition, BERS has

excellent heat dissipation performance. By precisely designing the intelligent heat dissipation system, BERS will dissipate heat sufficiently and efficiently during work, avoiding performance degradation and damage caused by overheating.

BERS has a built-in overload protection system, and there is a possibility that the battery is fully charged and therefore no further charging through energy recovery is allowed. To cope with a variety of situations, including driving downhill on a full charge, BERS will improve hydraulic brakes to ensure the safety of critical components such as batteries. Artificial intelligence calculates complex energy recovery strategies. Within a few milliseconds, electronic device sensors will decide which components to apply electrical or hydraulic braking. The driver will not feel the difference, only learn about it on the dashboard's power meter. BERS has met the requirements of high quality mechanical engineering products by virtue of these excellent characteristics.

The pure electric vehicle is directly driven by the motor, which has the characteristics of fast torque dynamic response and large torque output at low speed. The improper control of the motor torque leads to the uncomfortable driving experience of longitudinal movement of the vehicle and dizziness of the drivers and passengers [9, 10]. The manual mode is suitable for users with high demand for vehicle driving pleasure. The semi-automatic mode is suitable for use in intense driving conditions. In the semi-automatic mode, in addition to the driver's independent choice of release time, BERS electronic control system can detect the timing of each shift due to the connection to the driving computer, and use the motor to drive the shaft when the engine and the shaft are disconnected, so that the vehicle also has power output in the shift gap. Meanwhile, the electronic control system can automatically adapt the power to achieve the shift without fluctuations. In the fully automatic mode, the driver does not need to choose the output time by himself. In addition to the output during shift, BERS will also output when the engine is at low speed and low torque, and the clutch between the engine and the drive shaft is electronically controlled from disconnection to gradual occlusion, so that the engine is always maintained in the most efficient output range. The fully automatic mode is the most fuel economy. The most environmentally friendly output mode, suitable for use in non-strenuous driving environment.

5. Conclusion

BERS is a unique system that combines intelligence with efficient energy management. The core idea is to maximize the energy of the vehicle to meet the needs of different driving scenarios. Different from the traditional energy recovery system, BERS has an autonomous intelligent energy release function, which monitors the vehicle speed, acceleration, mileage and other key data in real time through sensors, accurately judges the best energy release time, and provides all-round power support for drivers.

BERS represents a revolutionary innovation in the field of energy management. Its unique design concept seamlessly integrates intelligence, efficient energy recovery, and flexible power output, ushering in boundless possibilities for both electric and combustion engine-driven vehicles. BERS not only extends the range of electric cars but also enhances driving experiences with greater flexibility and excellence. Its intelligent control system offers drivers various power output choices to adapt to diverse driving scenarios, striking an ideal balance between performance and environmental considerations.

As technology continues to evolve, BERS is poised to steer the course of development in energy management. Its AI-based control system, efficient energy conversion technologies, and innovative material applications are set to positively impact the future of automotive engineering and energy sustainability. Whether in minimizing energy wastage or enhancing vehicle performance, BERS demonstrates immense potential, positioning itself as a pivotal driving force in advancing automotive technology.

BERS is more than just an energy management system. It is a technology innovation with far-reaching implications. It inspires us to consistently pursue more efficient and intelligent ways of

utilizing energy, providing greater possibilities for the future of transportation, making our journeys more environmentally friendly, convenient, and enjoyable. BERS will lead to higher performance and comfort in EVs, with a positive impact on the entire mechanical engineering field.

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