ELECTROMAGNETIC COMPATIBILITY ANALYSIS OF THERMAL ENERGY RECOVERY POWER SYSTEM DRIVEN BY NEW ENERGY VEHICLES

by

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Original scientific paper
https://doi.org/10.2298/TSCI2302167Z

In order to ensure the stability of battery management power system, improve the reliability of on-board electronic products, and ensure the stability of thermal energy recovery power system, the author proposes an electromagnetic compatibility optimization scheme based on wiring harness, power module, and PCB noise, taking the battery management system of vehicle electronic components as an example, the role of electromagnetic compatibility on products is described, the hardware circuit is analyzed and designed by electromagnetic compatibility design theory to ensure the reliability of vehicle components. The electromagnetic stability of the power battery is guaranteed through the electromagnetic compatibility optimization analysis of the battery management system, so as to achieve more stable battery management. The experimental results show that each module of the battery management system works stably, and the disturbance degree test shows that the resonant noise of the battery management system disappears, and there is no obvious narrowband electromagnetic disturbance, and the overall value is below the limit of 20 dB. In conclusion the electomagnetic compatibility optimization scheme can effectively ensure the stability of the battery management power system, and indirectly ensure the stability of the heat recovery power system.

Key words: *new energy vehicles, electromagnetic compatibility, drive system, heat recovery system, electromagnetic stability*

Introduction

On July 9, 2012, the State Council issued a formal 2012-2020, energy saving and new energy automobile industry development cross gauge, with more attention paid to the new energy vehicles in China, the domestic many OEM are thriving Ma Xin energy automotive projects on the ground, the domestic many provinces and cities in the application of new energy vehicles such as new energy bus transit vehicle, electric taxis*, etc.* The car itself is a complex system, the traditional car because of ignition system, power generation system, motor, so there will be radiation. Interference not only reduces the reliability of the car itself, but also affects the work of the parts in the car. Compared with traditional vehicles, pure electric, hybrid, fuel cell and other new energy vehicles, their interference is especially serious, due to the use of electric drive system and high voltage components (DC/DC, DC/AC*, etc.*) in new energy vehicles, the interference is launched to the outside world. If the suppression measures are not enough, the

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inverter will have rich harmonic components, and then through the input and output line to the outside world, these interference components spectrum range is very wide, from tens of kilohertz to tens, hundreds of megahertz, cover even higher RF section, it can lead to other control automotive spare parts work failure, also can cause serious on AM radio frequency interference, will cause serious traffic accidents, for responsible attitude, the development of new energy vehicles stage will be tested many times, true and reliable test for spare parts and vehicle, in order to ensure the vehicle and vehicle components through the corresponding electromagnetic compatibility (EMC) standards.

China's automobile industry has developed rapidly, at present, China has become the first country in both production and sales of automobiles in the world, however, China is still in the golden age of automobile industry development in recent years, according to statistics, the number of cars per thousand people in the USA is more than 800, however, China has less than 200 cars per thousand people. China has a large population base, so China's auto industry will continue to develop. It can be seen that Chinese automobile develops rapidly after entering the 21st century. The development of the automobile industry is changing from traditional cars to new energy. At present, new energy vehicle manufacturers and parts factories are developing at full speed, the country has become the world's largest battery producer. In recent years, the development of new energy vehicles has doubled from nothing. In a broad sense, new energy vehicles are pure electric vehicles, plug-in hybrid electric vehicles, fuel cells and other non-fuel vehicles, and in a narrow sense, electric vehicles are considered to be pure electric and plug-in hybrid vehicles (plug-in hybrid electric battery range is more than 70 km). In the initial stage of new energy vehicle development, plug-in hybrid electric vehicles sold more, but with the understanding of electric vehicles, with the development of battery technology, more and more people choose pure electric vehicles. The development trend of automotive industry and automotive electronics makes automotive EMC more and more attention, a pure electric vehicle driving under the shortwave radio, the car suddenly lost power, and cannot start. But the tow truck was able to move the car after it was pulled away, here, the car is suffering from electromagnetic interference, the interference signal may cause the battery management system to misoperate, the high voltage relay of the power battery is disconnected and the battery cannot provide energy. The battery of pure electric vehicle is the only energy source of the car, the most important thing to ensure the reliability of the battery is to ensure the stability of the battery management system, the design of a battery management system is not only considering the function and safety factors, but also EMC. Environment, automobile, new energy, on-board electronics, all kinds of signs show that improving the reliability of on-board electronic products is the key work of the development of the current automobile industry.

Therefore, the author takes the battery management system of vehicle electronic components as an example to illustrate the role of EMC on products, the hardware circuit is analyzed and designed by EMC design theory to ensure the reliability of vehicle components. The EMC of the power battery is ensured through the EMC optimization analysis of the power system of battery management, so as to achieve more stable battery management [1].

Literature review

In recent years, the electric vehicle has developed from a concept vehicle to one of the models vigorously invested by the world's major automobile manufacturers. With the increasing attention paid to the energy problem by all countries, pure electric vehicles and hybrid electric vehicles are increasingly welcomed by all countries. By changing the principle of traditional internal combustion engine and using relatively clean batteries, we can achieve the

effect of low carbon and environmental protection, which is the change that electric vehicles bring to us. It is one of the most effective ways to solve the increasingly serious energy and environmental problems by developing electric vehicles to get rid of the demand for crude-oil in the human automobile industry. Compared with the automobile with traditional internal combustion engine principle, the electric vehicle has serious EMC problems at the moment of starting and during operation due to its different electric principle. High voltage and high power at the moment of starting will cause serious electromagnetic interference to the internal parts of the car. Because electric vehicles generally use a large number of cables as communication harnesses, the coupling between communication cables will also cause complex EMC problems. All these are directly related to the safety of cars and drivers. Therefore, how to protect and rectify the EMC performance in the stage of car design and certification test is an important aspect of current electric vehicle design.

According to the power generation mechanism of electric vehicles, electric vehicles can be divided into three categories: pure electric vehicles, hybrid electric vehicles, and fuel cell electric vehicles. These three types of electric vehicles are integrated with electric power system devices in varying degrees. The pure electric vehicle uses the battery or super capacitor to provide power, and uses the DC/AC inverter or DC/DC converter device to change the energy and provide it to the motor load for driving. For hybrid electric vehicles using internal combustion engines as the main power supply, the battery supercapacitor bank is responsible for providing auxiliary energy for work, and the two modules are interfaced through the generator. The fuel cell electric vehicle uses the fuel cell to provide the main power source, uses the battery and super capacitor bank to provide auxiliary power, and conducts energy flow management through power electronic devices.

The main components of power electronic devices are DC/DC converters and DC/AC inverters. This high power electronic device will produce electromagnetic interference during operation, which will make the whole vehicle run in an unstable state and seriously affect the normal operation of vehicle components. It is a strong source of electromagnetic interference. The rapid transient change of instantaneous voltage and current will produce high radiation and noise, especially the rapid rectification of components and electronic products, high current and high voltage of the motor during startup, which will produce high field strength conduction and radiation emission disturbance. This paper mainly discusses the form of conducted electromagnetic interference in the electric drive system of electric vehicles.

For the common mode interference, it is mainly through adding appropriate damping impedance between the body frame and the ground, so as to suppress the series resonance in the common mode current path to achieve the purpose of attenuating the common mode interference [2]. Although the OEM and parts manufacturers of the new energy to do EMC test, but still received complaints from owners, so hybrid vehicles and other new energy vehicles encounter an electromagnetic crisis, the reason is that its electromagnetic interference on the human body and although the jury is still out on environmental harm, consumers are right to be concerned [3]. The electromagnetic radiation has been listed by the World Health Organization as the fourth largest environmental organization after noise, water and atmosphere [4].

On the basis of the current research, the author proposes an EMC optimization scheme based on wiring harness, power module, and PCB noise, the electromagnetic stability of the power battery is guaranteed through the EMC optimization analysis of the power system of battery management, so as to achieve more stable battery management. Also indirectly ensures the stability of the thermal energy recovery power system [5].

Research methods

Because the electromagnetic interference problem of the high voltage system of new energy vehicles is more serious, the whole vehicle EMC performance test is more difficult to pass the national certification test. In view of these problems, this paper sorted out the EMC angle of new energy vehicles and the main electronic control components, and then put forward some specific suggestions and measures for EMC design from the perspective of the whole vehicle. The electromagnetic interference of new energy vehicles is serious. The main reason is that the driving motor, motor control, DC-DC, electric pool, high voltage air conditioning system and other high voltage and high current high power electronic equipment [6].

In addition, there is a high voltage system, which connects the battery, power system, motor and so on. There are other parts inside a new energy vehicle. For example, BMS, VMS, ECU, *etc.*, they can also emit electromagnetic interference. At the same time, they will also be subject to strong electromagnetic interference from the outside world, leading to their abnormal work, affecting the normal operation of vehicles, and causing very serious consequences for the cars in the running. Therefore, only by making EMC design for new energy vehicles from the source and taking preventive measures from the source can you solve this problem. This requires the EMC design and treatment of the main interference sources of new energy, respectively [7].

What is EMC? It refers to the compatibility of electric field and magnetic field, on the one hand, the equipment has good anti-interference and can work normally in the case of electromagnetic field interference. On the other hand, when the equipment is working normally, the electromagnetic field interference intensity is small and will not affect the normal work of other equipment around. The basic theory of EMC involves electromagnetic field and electromagnetic wave, circuit principle, signal analysis and processing, microwave and antenna, automotive electronics and electrical*, etc.*, its three elements are disturbance source, propagation path and sensitive equipment.

The main sources of harassment are electrical equipment in the surrounding environment, power electronic components, base stations, thunder and lightning (natural weather) and other external sources of harassment, there are also AC power motors, motor controllers, auxiliary system motors, power converters, solenoid valves, relays, ignition systems and other internal sources of automotive harassment. The propagation path (coupling path) is conduction coupling and radiation coupling, which coupling the energy from the disturbance source to the sensitive equipment to generate interference, affecting the normal operation of the equipment. Sensitive devices (*i.e.*, receivers) respond to external disturbances and cannot function properly, such as various controllers, sensors and other devices [8, 9].

With the maturity of electronic technology, high power radio technology and automotive electronic technology, automotive EMC is becoming more and more obvious. At present, the international automotive EMC standards include CISPR25, ISO11452, ISO7637*, etc.*, Europe has ECER10, the USA has SAE and other related standards, China's automotive EMC started late, and currently has GB/T18655, GB/T33014, GB14023, and other related standards. From the perspective of EUT, automotive EMC is divided into two parts: vehicle EMC and component EMC, the component EMC is the necessary link to ensure vehicle EMC. From the perspective of EMC, it can be divided into radiation emission, conduction emission, radiation immunity, conduction immunity and electrostatic discharge. Figure 1 shows the block diagram of automotive EMC classification [10].

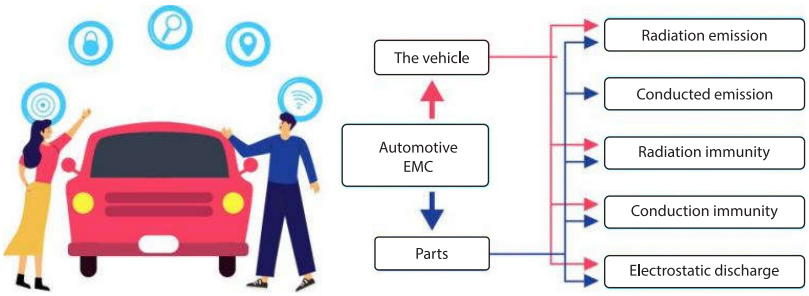

Figure 1. Classification diagram of automotive EMC

Battery management system harassment analysis

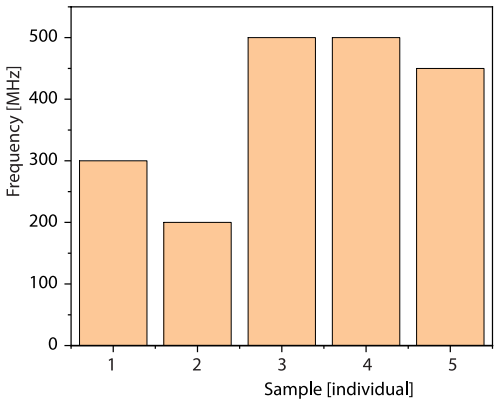

Figure 2. Exceeding frequency of 13 power batteries

According to the EMC of current EV battery systems, 13 battery manufacturers were randomly selected to conduct EMI radiation tests, the results showed that only four companies could pass the three-level limit of GB/T18655-2010 (commonly used limit of OEM), and the other nine companies all exceeded the limit in different degrees. Especially in the 150-450 MHz frequency band, the phenomenon of exceeding the standard is obvious. Among them, both narrowband signal and wideband signal have certain exceedance, especially narrowband signal, exceedance is more obvious at the resonant frequency point. Above 500 MHz, the radiation of the 13 sampling stations all met the Level 3 limit of radiation emission GB/T18655-2010. As shown in fig. 2, 13 power batteries exceed the standard frequency [11].

Through the aforementioned test results and reading related literature, the causes of battery management system harassment were analyzed. The disturbance sources of electromagnetic radiation in battery management system can be divided into the following aspects:

– A large number of power electronic switch parts in the system, such as IGBT, MOS, *etc.* produce extremely strong EMI noise.
– The pulse current and voltage of BUCK, BOOST and other switching power supply circuits contain rich high frequency harmonics, which will produce serious electromagnetic radiation.
– The power battery is connected with a high voltage wire harness, a low voltage wire harness and a variety of signal acquisition wire harnesses, which will be coupled to each other when the system works, thus forming complex EMI noise.
– The existence of high voltage wiring harness inside the system and the huge volume of battery pack make the electromagnetic coupling path more complex and variable.

The current test standard QC/T897 for battery management systems, the standard for EMC characteristics requirements in accordance with the relevant provisions of GB/T17619-1998, and GB/T17619-1998 stipulates the use of one or more methods to achieve narrowband electromagnetic radiation interference in the frequency range of 20-1000 MHz, this kind of disturbance signal with single bandwidth does not have the characteristics of typical signal com-

pared with the signal in the actual complex electromagnetic environment, so it is necessary to carry out the test through the actual collected electromagnetic signal. Not only the battery management system, but also the radiation immunity stipulated by GB/T32960.2-2016 of VCU and T-BOX are tested with reference to GB/T17619-1998, now the new GB/T33014 is launched, however, it is still narrowband electromagnetic harassment, including the narrowband electromagnetic radiation immunity stipulated in ISO11452 is a kind of harassment of narrowband, therefore, neither the immunity test stipulated in ISO11452 nor GB/T33014 can fully reflect the actual complex electromagnetic environment, complex electromagnetic environment is a kind of electromagnetic interference wave with complex bandwidth, complex frequency and complex modulation.

By collecting disturbance data from the electric drive system, it is a key technology to study the immunity test of battery management system for sensitive electronic devices to supplement the anti-interference characteristics of vehicle electromagnetic disturbance signal for low voltage sensitive components such as battery management system.

Optimize the electromagnetic compatibility of the battery management system

These EMC problems are analyzed and considered in the design of hardware circuits to form a system-level EMC optimization. When designing a battery management system, it is inevitable that there will be a lot of wiring harnesses, and various signal wiring harnesses are complicated and interlaced, adopting appropriate shielding and connecting the shielding layer with the earth can effectively avoid the coupling of external energy into the wiring harness, and improve the disturbance resistance of the wiring harness itself. Similarly, the shielding layer can isolate the noise of the wire harness into the ground network and reduce the disturbance of the wire harness energy. Shielding is an efficient and practical method for EMC. The power supply design is the most basic module to ensure the normal operation of battery management system, the transformer isolation method is used to isolate the power ripple of low voltage system, and the common mode filter is used to filter the secondary coil of the transformer. Enhance the disturbance resistance and disturbance resistance of PCB board. The power ground network and the power supply are equally important for PCB boards, when designing ground network, select relatively wide isolation mode. When placing the power island, the resonant point of the PCB should be avoided. In the optimized circuit, a transformer is added as the isolated power supply, and the corresponding π filter is designed in the second-

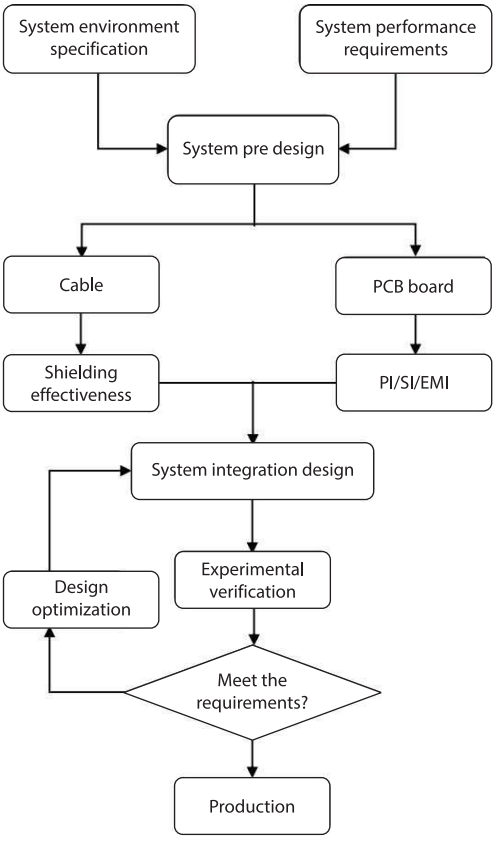

Figure 3. Design block diagram of EMC

ary coil of the transformer for filtering processing [12]. The whole circuit adopts the power island isolation structure, and the ground circuit also carries on the different segmentation optimization processing. When the system is assembled, all wiring harnesses and ground wires of the system are twisted, and the wiring harnesses are shielded. Figure 3 is the design block diagram of ECM.

Result analysis

The test results show that the battery management system can pass CISPR25:2016 Level 3 limits in one go, both for conduction and radiation, with a margin of nearly 20 dB to the limit. Figure 4 shows the test results of the harassment test process, the test frequency range is 30-200 MHz, it can be clearly seen from the fig. 4 that the difference between the peak value and the mean value is greater than 6 dB, the narrowband signal obviously disappears, and no obvious resonant signal appears, the test result is significantly lower than the limit value of 20 dB [13]. Through the optimization experiment, the optimization research on the battery management system plays an obvious role, which is suitable for improving the EMC of the system level battery management power system, can significantly improve the anti-interference characteristics of the battery management system, and can well inhibit the disturbance of the battery management system to the outside world [14].

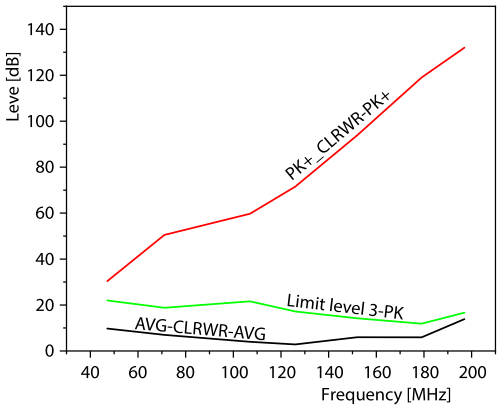

Figure 4. Test results of harassment degree

Conclusion

To sum up, three optimization schemes, shielding efficiency of shielded wire harness, power module and power ground isolation, were applied to the battery management system, and the interference immunity test was conducted, each module of the battery management system worked stably, the index displayed by the upper computer has no obvious fluctuation. The disturbance degree test shows that the resonant noise of the battery management system disappears, and there is no obvious narrowband electromagnetic disturbance, and the overall value is below the limit of 20 dB.

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Paper submitted: August 8, 2022
Paper revised: October 8, 2022
Paper accepted: October 26, 2022