ELECTRIC EQUIPMENT

1 Introduction

Automobiles are expected to constantly offer improved performance and functions to realize a mobility society that is sustainable, safe, and secure, as well as to satisfy a variety of different needs as a form of convenient and comfortable transportation. Furthermore, with the electrification of the powertrain, the advancement of driver assistance and automated driving functions, and the rise of connectivity, electric equipment continues to evolve and play a larger and larger role in building safe and secure vehicles that take functional safety into account.

On the environmental front, electric powertrains are now used in electric vehicles, hybrid vehicles, and fuel cell vehicles to help realize a carbon neutral society. At the same time, lingering issues with the cost of vehicle-mounted batteries, cruising range, and an insufficient recharging infrastructure, make it likely that internal combustion engines will also continue to coexist with electric motors for the foreseeable future, and efforts to achieve even higher efficiency internal combustion engines continue unabated.

Alternators and starters compatible with start-stop and regenerative braking systems are becoming more common in starting and charging systems, and the use of motor generators that perform both charging and starting, and of drive assist (mild hybrid systems) provided by 48 V high voltage, is also growing. In ignition systems, advances in the development of products compatible with hydrogen fuel, one of the carbon-neutral fuels, are expected. While electric power steering is already widespread, redundant and steer-by-wire systems that provide functional safety are being developed in anticipation of the era of automated driving.

Safety performance has now been included in the evaluation items of the new car assessment program and is becoming one of the basic automobile performance parameters, as well as a factor in the decision consumers make when they choose a vehicle. Preventive safety systems, such as collision mitigation braking systems and lane departure warning systems, are becoming more common and the development of even more advanced functions, such as danger avoidance via automatic steering, is underway. In Japan, the agreement rules of the World Forum for Harmonization of Vehicle Regulations (WP.29) are being applied one by one, and related laws and regulations are being developed.

Vehicle interiors are also evolving around human machine interface (HMI) technology that connects people with the vehicle to realize a more comfortable mode of transportation. The installation of larger and higher resolution display devices to provide easy-to-understand and accurate information, and of various HMI functions that utilize driver monitoring systems, is starting to become more common.

The amount of information handled by information and communications technologies has grown as on-board systems have advanced, creating greater demand for low latency and high reliability in these systems. In particular, in-vehicle communication networks are being developed to cope with the anticipated evolution of electrical and electronic architectures. The growing dependence on such forms of communication is making cybersecurity technologies more important than ever.

2 Technological Trends in Automotive Electric Equipment

2. 1. Electrification Products

Global warming has become a worldwide problem, and activities to reduce CO_2 emissions are vigorously pursued. Since strict emission regulations are established in the automotive industry to reduce CO_2, EVs and other electric-powered vehicles are expected to spread worldwide in the future. High efficiency will be required of electric vehicles to address issues such as reducing CO_2 emissions, they will also have to be priced attractively enough to be accepted by many users. The same requirements therefore apply to their component parts. At the same time, downsizing is also required. The main components are the drive motor, inverter, and secondary battery.

Using magnets in the drive motor is more efficient, but their price is an issue. Technology that increases efficiency while reducing the number of magnets is being developed. Efforts to reduce size and lower prices by increasing rotation speed are also underway, they present the challenge of maintaining efficiency.

The performance of inverters vary significantly depending on the on the power semiconductor. In the past, silicon (Si) was the mainstream, but silicon carbide (SiC) has recently come to be used. Silicon carbide offers higher efficiency and is more compact than silicon, but its price is an issue.

The eAxle, which integrates a motor, inverter, and gears, is also attracting attention. Integrating components makes it possible to reduce their size and price. They are likely to be installed in many electric vehicles.

Lithium-ion batteries are currently the mainstream secondary batteries, but solid-state and other next-generation batteries constitute promising eventual alternatives. Improvements have been made not only to electrolytes but also to electrodes. Expectations of increased energy density and lower prices, are leading to predictions that the spread of EVs will accelerate accordingly.

The rare metals used in magnets and batteries help improve electric vehicle performance, but present the drawback of being harmful to the environment. Looking beyond simply reducing CO_2 and also consider product reuse and recycling will become crucial.

2. 2. Electric Equipment for Charging Systems

Start-stop systems and active regenerative braking (micro hybrid systems) have become standard as fuel economy regulations become stricter around the world. Responding to the accompanying increased output demand for alternators requires not only making them smaller, but also raising their output and efficiency. Consequently, higher output density and higher efficiency in alternator power generation performance has been obtained through means such as a high-density winding of the stator coil, the mounting of magnets on the rotors to compensate for magnetic flux leakage, improving the cooling performance of the rectifier and regulator, and synchronous rectification by setting transistors in the rectifier. In addition, low-noise technology is increasingly relying on multiphase designs, where the number of stator winding phases is raised from three to five or six phases.

More effective use of regenerative braking is achieved by equipping the alternator with a regulator that enables fine-grained control via a host controller that employs a digital bidirectional communication interface such as local interconnect network (LIN) communication.

Furthermore, the use of the alternator as a motor is increasing the adoption of belt-driven motor generators with added engine restart and start assist functions. Replacing the alternator rectifier with an inverter enables the motor generator to provide not only power generation but also motor drive, which contributes to improved fuel efficiency through quiet engine restart and motor assist that uses regenerative braking power.

The emergence of electric power supply systems that replace conventional lead batteries with electric double layer capacitors and lithium-ion batteries is enhancing fuel efficiency through the recovery of larger quantities of braking energy and the drive assist energy. In conjunction with technological advances such as reducing semiconductor power loss, the adoption of a 48 V power supply voltage (mild hybrid) is becoming increasing common, especially in Europe and China. Electric equipment for charging systems remains a major product category that supports the spread of electrification.

2. 3. Electric Equipment for Starting Systems

Growing worldwide demand for stricter fuel economy regulations is resulting in more densely packed engine compartments due to electrification and additional auxiliary equipment such as turbochargers. Therefore, smaller, lighter, and highly efficient starters are required. In addition, many vehicles are now equipped with a start-stop system and use starters that can satisfy the far larger number of required engine starts as a result of improvements made to their sliding and wear parts to increase starter service life.

At the same time, other efforts to improve fuel economy have led to the adoption of systems that turn the engine off even before the vehicle comes to a complete stop to increase the length of time the engine is off. If the traffic signal changes from red to green at an intersection the vehicle is still slowing down to stop, the starter must be able to respond to a sudden demand to restart the engine (change of mind), and therefore have the ability to restart even before engine rotation stops completely.

Another issue is the momentary drop in battery voltage caused by the large inrush current that when an engine turned off by start-stop system is restarted. Wound field starters, one of the proposed solutions, can suppress the inrush current and mitigate the battery voltage drop, making it possible to alleviate the increase in the current capacity of components such as the battery. Furthermore, ways to meet comfort-related needs, including the downsizing of starters that can handle “change of mind” situations, and even quicker and quieter engine restarts, are being examined.

2. 4. Electric Equipment for Ignition Systems

The current mainstream ignition system for gasoline engines consists of multiple pieces of electric equipment such as spark plugs, ignition coils, and various sensors.

The sensors in the ignition system, which include angle sensors located on the crankshaft and camshaft, knock sensors that detect the state of combustion, in-cylinder pressure sensors, and ion sensors, are used as adjustment indicators for ignition timing and energy. More and more angle sensors feature a rotational direction detection function due to the increased use of start-stop systems and electric hybrid engines.

The reduction of carbon dioxide emissions by the United Nations Framework Convention on Climate Change (UNFCCC), has prompted the worldwide spread of regulations on the use of petroleum-derived fuels. In response electric motors are increasingly used in automobile powertrains. However, doubts about whether electricity alone can cover everything are prompting the development of an internal combustion engine compatible with carbon-neutral fuels.

Examples of carbon-neutral fuels include liquid synthetic fuels (e-fuels) made from carbon dioxide and hydrogen, biofuels derived from plants that take in carbon dioxide, and hydrogen fuels that do not contain carbon. Biofuels are already being used. Electric equipment for ignition system is based on existing equipment due to the premise that liquid synthetic fuel has the same characteristics as current gasoline.

With hydrogen fuel, the pressure in the combustion chamber pressure exceeds that of current engines. This is anticipated to raise the spark discharge voltage, and increases the frequency of abnormal combustion. Consequently, higher withstand voltages and output voltages in spark plugs and ignition coils, improved abnormal combustion detection accuracy from knock and in-cylinder pressure sensors, and advances avoidance control are expected.

2. 5. Steering

The number of vehicles that use electric power steering (EPS) is rising in response to the tightening of global fuel efficiency regulations and the expansion of driving support systems. In addition, the application of EPS with enhanced safety is accelerating due to the strengthening of safety requirements in preparation for automated driving systems, as well as to maintain compliance with ISO 26262 (Functional Safety).

Many current EPS systems consist of components (inverter, microcomputer, and sensors, etc.) set in a single system, which means that if any one component fails, the EPS stops and continuing to steer in autonomous driving mode becomes difficult. Therefore, EPS systems with redundant components are being developed to ensure continued steering even in the event of a malfunction. Furthermore, steer-by-wire (SBW) systems, which have no mechanical connection between the steering wheel in the vehicle and the rack in the engine compartment, have been applied in some vehicles. Greater adoption is expected, especially for level 3 or higher automated driving.

The development of automated driving systems enable heavy-duty trucks to drive in a platoon on highways is progressing and is expected to lead to the installation of EPS in heavy-duty vehicles that have conventionally used hydraulic power steering systems.

2. 6. Multiplex Communication Systems

With the rapid advances made in autonomous driving, connected vehicles, and electrification, the information handled by vehicle systems has diversified to encompass sensor, map, entertainment, and external information, and its volume has expanded at an explosive rate.

The speed and capacity of multiplex communication systems are being increased as quickly as possible to handle the growing amount of information. CAN with Flexible Data Rate (CAN-FD), which is faster than the current controller area network (CAN), and Ethernet with a maximum transmission rate of 10 Gbps are increasingly seeing partial adoption in electric equipment that requires higher speeds and larger capacity than existing systems.

There is also a growing need for coordination and cooperation with servers outside the vehicle via wireless communication involving different systems such as 4G and 5G mobile communication systems, to improve the driving performance, safety, and comfort of the vehicle system as a whole.

Two standard communication protocols, dedicated short range communications (DSRC) and cellular-V2X (C-V2X) have been proposed for vehicle-to-everything (V2X) communication that connects vehicles to a variety of entities. Development is being pursued while keeping an eye on communication regulation trends by authorities in various countries.

The electronic/electrical architecture of vehicle is also anticipated to move away from a decentralized system involving installing multiple application-specific devices in the vehicle to a centralized system that consolidates authority in one location and subdivides the vehicle into several zones controlled in coordinated manner. Reasonably latency-tolerant data, such as entertainment information, and data that requiring low latency and high-reliability transmission, such as sensor and control information, coexist on the same communication path. The application of time sensitive networking (TSN), which is increasingly considered for industrial use, is also being evaluated.

Network technologies and a cybersecurity measures that communication and fulfill communication requirements such as data communication within the system, high speed, large capacity, low latency, and high reliability, which change in conjunction with the evolution in vehicle functionality brought about by over the air (OTA), will take on greater importance.

2. 7. Vehicle-Mounted Information Systems

The number of vehicle navigation systems shipped in Japan in 2021 was 4.76 million units, a decrease of 8.4% from the previous year (according to the Japan Electronics and Information Technology Industries Association (JEITA)). Advanced functions, such as large high-resolution displays connected with safety functions that make use of camera images, continue to become more sophisticated, while audio systems with display screens offering more limited functions and optional navigation functions are increasingly popular, especially in markets outside Japan. In addition, the spread of smartphones and advances in mobile communications have allowed vehicles to connect to the Internet, accelerating initiatives to develop connected cars that create new value for consumers. Connected cars either feature an embedded communication module as standard on-board equipment, or rely on linking to the Internet via the user's smartphone. Technologies allowing onboard information systems to connect to smartphone applications or telematics services that use vehicle information or external real-time information, as well as over the air (OTA) systems that updates onboard device software via the Internet, are also being commercialized. Moving forward, entirely new markets related to the smart city concept are being created by vehicle-to-everything (V2X) technologies, which will support safer driving by enabling mutual communication between vehicles and other vehicles, the traffic infrastructure, and people, as well as by various mobility services that will make transportation more convenient. Despite their convenience, the various means of communicating with external sources acquired by vehicles also present a higher threat of hacking and underscore the importance of cybersecurity. This situation is expected to spark intensified efforts to enhance vehicle security.

2. 8. Displays and Instrument Panels

The role of displays and instrument panels as the interface between people and automobiles is becoming increasingly important. In particular, the growing number of safe driving support functions installed makes it crucial for the vehicle to convey the status of vehicle sensor detection and of related function operations to the driver in a safe and easy-to-understand manner. Instrument panel displays, center displays, and head-up displays (HUDs) are increasingly being introduced. Various refinements, such as increasing screen size, improving transmittance, and providing higher definition for instrument panels and center displays, demonstrate the added value offered by thin film transistor (TFT) LCD panels in the display devices of display equipment. Similarly, luxury vehicles are paving the way in introducing organic electro-luminescence (EL) to benefit from color reproducibility, thinner display screens, lower energy consumption and adaptability to curved interior surfaces. In HUDs, replacing the display method with the high-precision display digital light processing (DLP) or low energy consumption laser scanning microelectromechanical systems (MEMS) projection systems is under consideration. In addition, augmented reality (AR) displays that present information in a manner more easily accessible to the driver, such as by using a large HUD in conjunction with a driver monitoring system that detects the position of the driver's eyes and adjusts the display position accordingly to superimpose it over the scenery in front of the vehicle, are being developed and evaluated.

In addition to securing safe visibility, the introduction and spread of displays and instrument panels is expected to continue to serve as a means of promoting the evolution of easy-to-understand in-vehicle functions.

2. 9. Audio Systems

The number of vehicle CD player systems shipped in Japan in 2021 was 457,000 units, a major decrease of 28.8% from the previous year (according to JEITA). They are being replaced by a mobile information device linkage function that enables smartphones and portable music players to be operated from in-vehicle devices. In particular, equipment that uses distributed content such as internet radio in conjunction with smartphone apps is becoming more common. Car navigation systems and audio systems with display screens that incorporate this function have become mainstream. Currently, Bluetooth is the main form of wireless communication used to connect to these portable information devices, and the installation of wireless charging technologies to supply electric power is gradually expanding. At the same time, demand for radio broadcasts remains high, and digital radio broadcasting is particularly popular in North America. In Europe, efforts to implement digital audio broadcasting (DAB) are being stepped up as various national governments promote the transition to digital radio, and the installation rate of digital broadcasting receivers is expected to rise in conjunction with increased use of streaming application functionalities such as the aforementioned Internet radio.

2. 10. Safety Devices

In 2021, the number of traffic accident fatalities in Japan was 2,636 people, the lowest total since 1948. The high proportion of pedestrian and cyclist fatalities calls for initiatives to reduce such accidents.

The Japanese government is working to introduce driver assistance technologies that are effective at preventing traffic accidents. The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has applied the "Agreement Regulation on Collision Damage Mitigation Braking Control Devices for Passenger Vehicles (No. 152)" enacted by the World Forum for Harmonization of Vehicle Regulations (WP.29) in Japan since 2021, and made the installation of vehicle and pedestrian collision mitigation braking systems compliant with that regulation mandatory. Furthermore, the Regulation was revised in 2021 to add stipulations on technical requirements for bicycle collision mitigation braking systems. The additional stipulations will come into effect in Japan in 2024.

In 2021, the MLIT has also introduced the international standard concerning lane change support functions while the driver is holding the steering wheel, a new stipulation in UN Regulation No. 79 - Uniform Provisions Concerning the Approval of Vehicles with Regard to Steering Equipment and adopted by WP29, in Japan.

In March 2018, that same ministry took formulated the world's first guidelines for systems that rely on automated driving technology to move the vehicle as far onto the shoulder as possible and stop if the driver is unable to continue driving due to a medical emergency (roadside emergency driving stop systems). The contents of these guidelines were also reflected in international standards. The revision of the Uniform Provisions Concerning the Approval of Vehicles with Regard to Steering Equipment (Regulation No. 79) agreed upon at WP.29 in 2021 stipulates them as part of the performance requirements for risk reduction functions. This stipulation will come into effect in Japan in 2023.

In fiscal 2018, the Japan New Car Assessment Program (JNCAP) added pedestrian collision mitigation braking systems used at night with streetlights, high-performance front headlights, and acceleration suppression devices when the accelerator is depressed by mistake, to the active safety performance evaluation. Starting in fiscal 2019, pedestrian collision mitigation braking systems used at night without streetlights have been added to the evaluation items. Starting in fiscal 2021, bicycle collision mitigation braking systems were also added to the evaluation items.

Automakers and suppliers are expected to collaborate to introduce advanced safety technologies that incorporate these new standards and NCAP evaluation items.