ELECTRIC EQUIPMENT

1 Introduction

To achieve 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, automobiles are expected to constantly offer improved performance and functions. Furthermore, with the electrification of the powertrain, the advancement of driver assistance and autonomous 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 low-carbon 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. Higher compression ratios, supercharging, and higher efficiency internal combustion engines, such as compression-ignition gasoline engines are increasing the amount of ignition energy required in the ignition system. 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 autonomous 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. Furthermore, Japan has revised the Road Transport Vehicle Act and the Road Traffic Act to approve level 3 autonomous driving (conditional autonomous driving) as of 2020, and development targeting widespread autonomous driving is being pursued.

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 becoming 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. Advances can also be seen in development based on cellular-V2X, which uses in-vehicle Ethernet and fifth generation mobile network technology. 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. 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, and responding to the accompanying increased output demand for alternators requires making them smaller, as well as raising their output and efficiency. Consequently, higher output density and higher efficiency in basic alternator electric 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 to five or six phases from the conventional three.

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 digital bidirectional communication interfaces such as a pulse width modulation (PWM) signal communication interface or local interconnect network (LIN) communication.

Furthermore, the use of the alternator as a motor is making belt-driven motor generators with added engine restart and start assist functions more widespread. The motor generator enables not only electric power generation, but also fully electric motor drive by replacing the rectifier in the alternator with an inverter. This contributes to better overall fuel efficiency because the motor assist, which employs quiet engine restarting and regenerative braking energy, reduces the vehicle's fuel consumption.

The emergence of electric power supply systems that replace conventional lead batteries with electric double layer capacitors and lithium-ion batteries is enhancing fuel economy through the recovery of larger quantities of braking energy and the expansion of the amount of 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. Electric equipment for charging systems remains a major product category that supports the spread of electrification.

2. 2. Electric Equipment for Starting Systems

Growing worldwide demand for stricter fuel efficiency regulations is resulting in more densely packed engine compartments due to the electrification and addition of auxiliary equipment such as turbochargers. Therefore, there is continuing demand for smaller, lighter, and highly efficient starters. 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 thanks to the longer service life achieved through improvements made to their sliding and wear parts.

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. 3. Electric Equipment for Ignition Systems

The ignition system consists of multiple pieces of electric equipment such as spark plugs, ignition coils, and various sensors. With the tightening of fuel efficiency regulations, development related to the variable compression ratio, super lean burn, and other further improvements in internal combustion thermal engine efficiency encompass higher voltage discharge sparks, maintaining strong sparks, spark plugs and ignition coils that withstand high voltages, higher voltage output, higher energy, and spark plug electrode materials that are more resistant to high-energy discharges.

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. With supercharging and other innovations increasing the occurrence of abnormal combustion and making more advanced ignition timing control a necessity, a method of digitally processing the knock sensor signal directly into the computer is being introduced. Other attempts to achieve advanced combustion control involve the use of in-cylinder pressure sensors and ion sensors that directly capture information within the combustion chamber.

New electric equipment for the ignition system, such as low-temperature plasma discharge devices, is also being developed. A compression-ignition gasoline engine has been developed in response to stricter fuel economy regulations and low-temperature plasma is expected to assist this compression ignition technology.

Policies to ban the sale of automobiles powered only by combustion engines have been announced in several countries, but the use of gasoline engines is likely to continue in a majority of electric hybrid systems. Ignition systems will also undoubtedly remain a key technology for enhancing the efficiency of engines.

2. 4. HVAC Equipment

Innovations in HVAC systems are required to reduce the amount of CO_2 emissions from vehicles.

Since they have no engine that is the heat source for the HVAC, electric vehicles relied on electric heaters for heating, but such vehicles are now being equipped with heat pump systems featuring high heating efficiency to avoid reducing their cruising range. Although ensuring sufficient heating performance at extremely low outside air temperatures had been an issue for heat pump systems, the introduction of injection technology that uses a compressor to compress the gaseous refrigerant after it passes through the radiator has enabled heating when the temperature is below the freezing point. In addition, systems that use the waste heat from the inverters, motors, and batteries as a potential heat source are also being studied.

Furthermore, in preparation for advanced driving support and autonomous driving, technology that detects driver drowsiness and controls the airflow and temperature to keep the driver alert is being developed. Expectations that the HVAC system will also offer new added value are rising.

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 development of EPS with enhanced safety is accelerating due to the strengthening of safety requirements in preparation for autonomous driving systems and 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, are being studied for autonomous driving of level 3 or higher, and are expected to see greater adoption.

The development of autonomous driving systems allowing heavy-duty trucks to drive in a platoon on highways has already begun and is expected to lead installing EPS in heavy-duty vehicles that have conventionally used hydraulic power steering systems.

2. 6. Displays and Instrument Panels

The role of displays and instrument panels as the interface between people and automobiles is becoming increasingly important. This is particularly true for automobiles below autonomous driving level 4, in which it is essential for the vehicle to pass on driving support information and alerts about the state of the vehicle to the driver. The development of more advanced instrument panel displays, center displays, and head-up displays (HUDs) to present these various kinds of information is underway. Various refinements, such as improving transmittance, adjusting partial brightness, and introducing curved shapes, are enhancing the functionality of thin film transistor (TFT) LCD panels for the display portion of instrument panels and center displays. Similarly, factors such as better color reproducibility, thinner display screens, lower energy consumption, and adaptability to curved interior surfaces are anticipated to trigger greater adoption of organic electroluminescence (EL). For HUDs, replacing the conventional TFT LCD panels with digital light processing (DLP) to display information with greater precision, or with laser scanning microelectromechanical (MEMS) projection systems that consume less electrical power is under consideration.

In addition, augmented reality (AR) displays that present information to the driver in a more easily recognizable way by, for example, using a large-size HUD in conjunction with a driver monitoring system that detects the position of the driver's eyes and adjusting the display position accordingly to superimpose it over the scenery in front of the vehicle are being developed, indicating the interest in displays and instrument panels that foster closer communication between vehicles and their occupants.

2. 7. 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 100 M to 1 Gbps transmission rate are increasingly being adopted in portions of electric equipment that require 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.

Technologies that enable communication control and cybersecurity measures encompassing wireless communication will become increasingly important for multiplex communication systems.

2. 8. Vehicle-Mounted Information Systems

In vehicle navigation systems, 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 on-board information systems to connect to telematics services that use vehicle information or external real-time information, as well as with smartphone applications, are also being commercialized.

Moving forward, entirely new markets are being created by V2X technologies, which will support safer driving by enabling communication between vehicles, communication between vehicles and the traffic infrastructure, and between vehicles and people, as well as by over the air (OTA) technologies that allow the software in on-board equipment to be updated via the Internet and 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, a situation that is sparking intensified development of vehicle security technologies.

2. 9. Audio Systems

In contrast to the drop in the number of car CD players, demand for portable information devices that enable the operation of smartphones and portable music players from on-board devices is rising.

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 are expected to increase in number and popularity in the future.

Currently, Bluetooth is the main form of wireless communication used to connect to these portable information devices, and supplying electric power via wireless charging technologies is predicted to become more widespread in the near future.

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 continue to rise.

2. 10. Safety Devices

In 2019, the number of traffic accident fatalities in Japan was 3,215 people, the lowest total since the National Police Agency started recording statistics in 1948. However, as in the previous year, elderly people aged 65 or older continued to account for more than half of these fatalities keeping that percentage at a stubbornly high level. Broken down by situation, pedestrians and vehicle passengers continue to make up the majority of fatalities, followed by people on motorcycles and then people riding bicycles.

These circumstances are spurring Japanese government efforts to introduce driver assistance technologies that are effective at preventing traffic accidents. In March 2018, the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) was the first government agency in the world to establish guidelines for systems (driver emergency response systems expanded to pull over on the road shoulder) that use autonomous driving technology to bring the vehicle as far onto the shoulder of the road as possible and then stop it if the driver is unable to continue driving due to a medical emergency. Furthermore, as a part of its measures to prevent traffic accidents by elderly drivers, MLIT established a national system to certify that collision mitigation braking systems for passenger vehicles have a certain level of performance. This was done at the request of automakers and implemented in April.

In addition, the MLIT announced that Japan would introduce UN Regulation No. 144 - Accident Emergency Call Systems (AECS) adopted by the United Nations Economic Commission for Europe (UNECE) World Forum for Harmonization of Vehicle Regulations (WP.29) starting in 2020, and the new international standard stipulated in UN Regulation No. 79 - Uniform Provisions Concerning the Approval of Vehicles with Regard to Steering Equipment concerning support functions for lane changes while the driver is holding the steering wheel in 2021. Revisions to the Road Transport Vehicle Act and the Road Traffic Act successively approved during the 2019 ordinary Diet session will lift the ban on level 3 autonomous driving in Japan in 2020.

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.

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