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 automobile issues such as the cost of vehicle-mounted batteries or cruising range, and social infrastructure issues such as the availability of recharging, make it likely that coexistence with internal combustion engines will continue for the foreseeable future. Efforts to achieve even higher efficiency internal combustion engines therefore continue unabated.

Alternators and starters compatible with start-stop and regenerative braking systems are becoming more common in starting and charging systems. 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-making of consumers 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 revised its Road Traffic Act to permit Level 4 automated driving starting in 2023, spurring development aimed at the social implementation of transportation services.

Human machine interface (HMI) technology that connects people with the vehicle to realize a more comfortable mode of transportation is also evolving. 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 advances in 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. 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 power 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-acid batteries with electric double layer capacitors and lithium-ion batteries is enhancing fuel efficiency through the recovery of larger quantities of braking energy and 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 economy regulations is resulting in more densely packed engine compartments due to electrification and additional 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 as a result of improvements made to the sliding and wear parts of starters.

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 while 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 generated when restarting an engine turned off by the start-stop system. 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, as well as 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.

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 powertrains are increasingly used in electric and other vehicles. However, doubts about whether electricity alone can cover everything are prompting the concurrent development of internal combustion engines adapted to carbon neutral fuels.

Examples of carbon neutral fuels include carbon-free hydrogen fuel, plant-derived biofuel, and liquid synthetic fuel (e-fuel) made from carbon dioxide and hydrogen.

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 in avoidance control are expected.

There are already biofuels in use, and electric equipment for ignition systems follows existing designs based on the premise that liquid synthetic fuel has the same characteristics as current gasoline.

2. 4. HVAC Equipment

Electric vehicles, a crucial option for achieving carbon neutrality, have relied on electric heaters because they do not have the engine that serves as the heat source for the HVAC system. However, heat pump systems featuring high heating efficiency are increasingly used to enable even longer cruising ranges. 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 heat source for heaters are coming into use.

The need for rapid charging is also growing to further extend cruising ranges through as-needed additional charging. This requires battery cooling functionality to mitigate heat generation by the battery during rapid charging.

Heat management systems that feature both a heating and a cooling circuit, and switch to the optimal circuit based on the vehicle state or surrounding environment, are being developed and adopted for the above mentioned heating and battery cooling functionalities.

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 are now used, especially in electric vehicles. Greater adoption is expected, especially for Level 3 or higher automated driving.

Progress in being made in the development of automated driving systems that enable heavy-duty truck platoon driving on highways, and EPS use is expected to expand to heavy-duty vehicles that have conventionally used hydraulic power steering systems.

2. 6. Multiplex Communication Systems

With the rapid advances made in automated 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), as well as Ethernet with a maximum transmission rate of 1 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 electrical and electronic architecture of vehicles 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 cybersecurity measures that 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) updates, will take on greater importance.

2. 7. Vehicle-Mounted Information Systems

The advanced functions of vehicle navigation systems, such as large high-resolution displays connected with safety functions that make use of camera images, continue to become more sophisticated. At the same time, 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 software over the air (SOTA) systems that updates on-board device software via wireless communication, have also been commercialized. Moving forward, entirely new markets such as the smart city concept are being created by vehicle-to-everything (V2X) technologies, which support safer driving by enabling mutual communication between the vehicle and other vehicles, the traffic infrastructure, and people, as well as by various mobility services that rely on the social infrastructure to 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 further underscore the growing importance of cybersecurity, a situation that is sparking intensified development of technologies that enhance 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 on-board 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 to provide all that information. 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 is leading to the adoption of organic electroluminescence (EL) starting with luxury vehicles. 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. 9. Audio Systems

The number of vehicle CD player systems shipped in Japan in 2022 decreased to 377,000 units (17.5% less than the previous year and 88.7% less than in 2012, 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 functionality to supply electric power to those portable devices 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. The installation rate of digital broadcasting receivers is therefore expected to continue to rise in conjunction with increased use of streaming application functionalities such as the aforementioned Internet radio.

2. 10. Safety Devices

In 2022, the number of traffic accident fatalities in Japan was 2,610 people, reaching its lowest total for a sixth consecutive year 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. 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. In 2021, that Ministry has also introduced the international standard concerning lane change support functions while the driver is holding the steering wheel in Japan. This is a new stipulation in UN Regulation No. 79–Uniform Provisions Concerning the Approval of Vehicles with Regard to Steering Equipment that was adopted by WP.29.

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 content of the guidelines, which come into effect in Japan in 2023, has been incorporated in international standards.

In addition, the Ministry proposed the addition of close-proximity front and lateral vision/detection devices to international regulations to prevent accidents involving hitting a pedestrian or other road user when the vehicle takes off. The new UN regulation was approved in November 2022 and is scheduled to be issued in 2023.

In September 2022, there was a tragic accident involving a kindergarten child left in a bus and dying of heat stroke in Japan. Safety devices that help prevent leaving someone behind in shuttle buses will become mandatory in April 2023. Vehicles are now expected to play a role in helping protecting lives not only during driving, but also before and after.

In 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 2019, pedestrian collision mitigation braking systems used at night without streetlights were also added to the evaluation items, and cyclist-aware collision mitigation braking system tests were added in 2022.

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