ELECTRIC EQUIPMENT

1 Introduction

To achieve a society that is sustainable, safe, and secure, as well as to meet diverse needs as a convenient and comfortable means of transportation, automobiles are expected to constantly offer improved performance and more advanced functionality. Furthermore, the use of communications to connect automobiles with their surroundings calls for meeting even higher level requirements. The role played by electric equipment in meeting such requirements is constantly growing.

In terms of environmental concerns, the use of electricity as a means of propulsion to reduce CO_2 emissions, as exemplified by electric and hybrid vehicles, is becoming more prevalent, and fuel cell vehicles have also entered the market. On the other hand, conventional engines are anticipated to remain the primary means of automobile propulsion for the foreseeable future, and efforts to raise their efficiency are actively being pursued. Starting and charging systems continue to exhibit advances in the alternators and starters, which constitute the key elements of start-stop and regenerative braking systems. Belt driven motor-generators, which allow quiet and quick engine restarts, are also being used with increasing frequency. Ignition energy requirements are increasing due to refinements that increase engine thermal efficiency, such as higher compression ratios and the adoption of lean-burn combustion. The growing use of electric power steering in medium and luxury vehicles is spurring the development of systems that ensure safety in the event of a failure to achieve compliance with the functional safety standard (ISO 26262).

The rate of installation of collision mitigation braking, or lane departure warning, and other active safety systems is rising rapidly, and the use and development of vehicles equipped with such systems is being promoted through means that include making active safety systems mandatory on heavy-duty vehicles, and implementing assessments of the performance of those systems. The pace of public-private initiatives to realize automated driving is also accelerating, fueling expectations for further contributions to reducing traffic accidents.

On the level of comfort and convenience, the growing application of information and communication technology such in-vehicle information systems that can use various services through coordination with smartphones and roadside-to-vehicle cooperative systems that increase safety and convenience through wireless communication with the infrastructure, is emphasizing the importance of creating human machine interfaces (HMIs) that enable the safe, intuitive and easy-to-understand operation of such systems even while driving. Instrument panels relying on liquid crystal displays to selectively present high priority information, and head-up display (HUD) systems, which involve little eye movement time are also becoming more common. The growing need for unfettered voice operation of those systems is making coordination with cloud-based voice recognition functionality a necessity.

The application of information and communication technology is not limited to convenience and comfort, but rather also extends to improving environmental performance and supporting safe driving, with both coordination between various mounted devices and communication with external devices becoming more and more prevalent. As such technologies make in-vehicle networks larger, faster and more diverse, security technologies will play a critical role.

2 Technological Trends in Automotive Electric Equipment

2. 1. Electric equipment for charging systems

As automotive fuel economy regulations become stricter, regenerative braking and start-stop systems are becoming standard, requiring more efficient, higher output alternators to increase recovery ability of kinetic energy in deceleration and handle increased power demand.

In terms of alternator basic performance, improved power density is obtained through means such as denser stator windings, the mounting of magnets on rotors to compensate for leakage flux, enhanced rectifier and regulator cooling performance, and the adoption of synchronous rectification, which replaces the rectifier diodes with transistors. Multiphase designs, where the number of stator winding phases is raised to 5 or 6 phases from the traditional 3 is becoming more common as a low-noise technology.

To optimize control of the amount of generated power, digital bidirectional communication interfaces such as pulse width modulation (PWM) or local interconnect network (LIN) communications have been adopted for regulators, with an upstream controller enabling fine-grained control.

In start-stop systems, belt driven motor-generators that are quiet and offer prompt engine restarts by having the rectifier in the alternator substitute for the inverter not only to generate power, but also drive, have been introduced. In addition, greater energy recovery during deceleration and drive assist making use of that energy are contributing to improved fuel economy.

The introduction of systems that replace lead-acid batteries with electric double layer capacitors or lithium-ion batteries as devices to store the recovered electrical energy is enhancing fuel economy through the recovery of larger quantities of energy and the expansion of the amount of drive assist. Moreover, the trend toward switching to a 48V supply voltage suggests that electric equipment for charging will continue to be enhanced to achieve improved fuel economy.

2. 2. Electric equipment for starting systems

The growing number of auxiliary devices around the engine, and the shorter distances between those devices brought about by engine downsizing, are reducing the space available to install starters. This is creating a need for smaller and lighter starters, which is being addressed through initiatives to make them more efficient, such as broadening the reduction ratio in the planetary gear mechanism and enhancing the performance of field magnets.

At the same time, the number of vehicles equipped with start-stop systems has been increasing rapidly in response to rising demand for improved fuel efficiency. In those systems the starter initiates a significantly larger number of engine starts than in the past, and high durability starters with reinforced sliding and wear portions are becoming more common. Another issue is the momentary drop in battery voltage caused by the large inrush current that flows when the starter activates to restart a stopped engine. This has led to the development of small field winding-based starters which are effective at mitigating the inrush current and excel in terms of rapid starts and durability. In addition, systems that use inertial propulsion and stop the engine just before the vehicle stops or while it is running to increase the duration of engine stops are being studied. If such systems are adopted, the frequency of engine restarts will increase even further, and starters will have to become even more durable. There are also development efforts directed at shortening start-up time and reducing start-up noise to address issues of response and comfort when the engine is started.

2. 3. Electric equipment for ignition systems

Ignition systems consist of ignition coils at each cylinder, and angle sensors that are located on the crankshaft and camshaft, and more sophisticated controls, as well as smaller and lighter component parts are needed to make installation easier and respond to the requirements of higher thermal efficiency and downsizing aimed at improving fuel efficiency.

Digital output type of angle sensors that have excellent signal detection precision and signal control, that are easy to install, that can be mounted directly on the engine and that can detect the angle directly from the crankshaft and camshaft have become the mainstream type of sensors. In recent years, angle sensors with a direction of rotation detection function have been adopted to improve engine restart performance after start-stop. These angle sensors can accurately detect the angle even when the crankshaft has returned in the opposite direction after the engine stops.

The pursuit of improved thermal efficiency, is leading to the adoption of variable valve mechanisms and direct injection, as well as more complex engine cylinder heads. At the same time, engines are becoming smaller, leaving very little space to mount electric equipment for ignition systems. In contrast, refinements such as higher compression ratios, higher turbocharging pressure, and higher ratio of exhaust gas recirculation (EGR) are increasing ignition energy requirements.

Ignition coils come in the spark plug hole-type, where the winding portion of the coils is housed within the spark plug holes of the engine, and plug top coils that are laid out on the top of the engine, and the use of the latter has been increasing due to the high efficiency of the magnetic circuits and the high flexibility for the high voltage path.

Small spaces have made spark plugs with an M12 screw diameter mainstream, and M10 diameter plugs are also coming into use. Materials with higher durability are being developed in response to the high voltage of the discharged spark and higher levels of energy.

Ion current detection systems that sense the ion produced during combustion have been commercialized as a means of achieving more precise control of combustion in ignition systems. In addition, new ignition systems such as multiple ignition as well as plasma and laser ignition are being developed to further increase engine thermal efficiency, and electric equipment for ignition systems is anticipated to remain an important part of key technologies to realize engines that are more environmentally friendly.

2.4. HVAC equipment

Innovations are required to HVAC systems in response to new regulations on refrigerants, as well as to adapt the systems to the major changes being applied to powertrains to address environmental issues.

Since they have no engine, electric vehicles relied on electric heaters as the heat source for the HVAC system, but such vehicles are now being equipped with heat pump systems featuring high heating efficiency to avoid reducing their cruising range. Nevertheless, ensuring heating performance at extremely low temperatures remains an issue, and improvements in that performance is being pursued through the study of systems that recover waste heat from inverters, motors and batteries.

The conventional mainstream refrigerant HFC-134a was adopted as a replacement for certain specified chlorofluorocarbons (CFCs). However, this refrigerant also has a large global warming potential (GWP) of 1,300 and the European Union (EU) issued a European Directive that made it mandatory for all new vehicles released after January 2013 to use a refrigerant with a GWP of less than 150, leading to the gradual adoption of a new refrigerant called HFO-1234yf. Although HFO-1234yf was initially said to produce a toxic gas if ignited in an accident, its safety was confirmed by the European Commission's highest organization for science and technology in March 2014. At the same time, the partial use of CO_2 refrigerants, which have a lower environmental impact, has begun. However, those refrigerants must be used under high pressures, creating issues concerning increased weight and cost for the system.

In addition, the discrepancy between the test cycle fuel economy and actual fuel economy is drawing attention. The effects of HVAC is a major cause of this discrepancy, and taking fuel economy into account during air conditioner use is being assessed for the next stage of the fuel economy and emissions test procedure (World-wide harmonized Light vehicles Test Procedure (WLTP)) that will come into effect in Europe around 2017.

2.5. Steering

Since electric power steering (EPS) is more fuel-efficient than conventional hydraulic power steering, it is used in an increasing number of models as fuel economy regulations are being strengthened worldwide. Although it was mainly used in compact vehicles until now, improvements in the EPS motor output have made it more common in medium and luxury vehicles, including SUVs and pickup trucks, and it is found in many new models launched in recent years.

Steering control has been commercialized as part of the cooperative control in driving support systems such as systems that provide lane keeping assist or traffic jam assist, as well as parking assistance systems that coordinate with vehicle peripheral monitoring systems.

Increasingly high-level safety requirements that encompass the growing adoption of EPS in luxury vehicles, as well as measures related to the official release of a functional safety standard (ISO 26262) in 2011, are pushing the development of EPS systems with enhanced safety in the event of a failure, and systems that build redundancy into inverters and motor windings to enable continued steering assist in the event of a failure in one of those units are being introduced in the market. Similarly, EPS systems that unfailingly allow continued steering in the event of a failure are being studied as part of measures to achieve advanced automated driving in the future.

2.6. Displays and instrument panels

Vehicle display devices such as the center screen for the navigation system or the instrument panel that contains the speedometer are evolving rapidly as devices that provide information for safe, secure and comfortable driving.

More and more instrument panels now use a large full screen with a full liquid crystal graphic display that includes the speedometer. Center screens are also becoming larger, and monitors featuring 17-inch liquid crystal displays have been introduced.

Along with larger screen sizes, technologies spread by smartphones and tablets are also being adopted. Technologies commercialized in the consumer market, such as screens with high definition, multi-touch operation provided by capacitive touchscreens and optical bonding, which prevents glare from external light sources by laminating a cover glass over the liquid crystal panel, are finding their way into automobiles after their reliability in automotive applications has been ensured.

Additionally, HUDs are also becoming more common and contributing to providing drivers with a safer and more secure driving environment.

In terms of design, development efforts that seek greater shape flexibility include curved displays and rear projection screens that project images from behind a free-form display. At the same time, advances in stereoscopic vision functions such as 3D displays and user interface improvements such as gesture input are expected to bring about even easier-to-use display equipment.

The display devices of the future will continue to play a crucial role as information devices that support safe and secure driving. Moreover, augmented reality (AR) and other technologies are creating expectations that devices will continue to evolve in the direction of realizing comfortable driving and improved quality of life.

2. 7. Multiplex communication systems

Multiplex communication systems are growing in scale and complexity as active safety functions and information and communication functions are becoming more comprehensive. Current industry standard networks, including the controller area network (CAN), FlexRay, LIN, and Media Oriented Systems Transport (MOST) are used in control, body and information systems in accordance with their respective areas of application.

The growth in the amount of information handled by various on-board units as they gain more advanced functions is spurring the adoption of automotive Ethernet, which is capable of 100/1,000 Mbps transmission in areas that require higher speeds than existing networks can provide.

There is also a growing need for coordination and cooperation between different systems and with servers outside the vehicle through wireless communication to improve the dynamic performance, safety, and comfort of vehicle systems as a whole, and the gateways that mediate those communications represent a critical function. Communication control technology, including external wireless networks, and security technology will become increasingly important.

2. 8. Vehicle-mounted information systems

The number of vehicle navigation systems shipped in Japan in 2015 was 5,270,000 units, a minor decrease, 97% of the previous year (according to the Japan Electronics and Information Technology Industries Association (JEITA)). The shift away from hard disk drives (HDDs) to the use of flash memory as a storage medium is well underway, with the latter accounting for approximately 94% of the total, leading to lower prices.

For devices, advanced functionality such as the installation of safety functions that leverage camera images and large displays continues to grow, display and audio units with streamlined functions that make the navigation system optional are gradually spreading.

In addition, the rapid spread in the use of smartphones has led to a corresponding increase in vehicle information system formats that can coordinate with smartphones. Supplementing telematics services that acquire and use probe and driving history data and navigation services that capitalize on the diversity of smartphone applications and the convenience of obtaining the latest information, major smartphone industry players are taking the lead in bringing out frameworks (Apple's CarPlay and Google's Android Auto) that allow on-board information systems to operate standard smartphone applications.

A safe and secure framework to update software and applications using wireless communication is expected to be introduced in the future. In the area of coordination with the infrastructure, shipments of conventional on-board Vehicle Information and Communication System (VICS) devices stood at a total 47,340,000 (as of June 2015, according to the Vehicle Information and Communication System Center), and next-generation roadside-to-vehicle cooperative systems such as intelligent transportation systems (ITS) spot-compatible dedicated short range communications (DSRC) systems or Green Wave, which coordinate with traffic signals, are expected to become more widespread.

2. 9. Audio systems

Although the number of car CD players shipped in Japan dropped to 2,600,000 in 2015 (12% less than the previous year), the number of display-equipped CD players reached 1,060,000, a significant increase (49% more than the previous year) and are expected to see continued growth in conjunction with the tendency to use them with parking assist cameras and in coordination with smartphones ((sales data according to the Japan Electronics and Information Technology Industries Association (JEITA)).

The demand for coordination with mobile information devices that allows smartphone and portable music players to be operated from on-board devices continues to grow. To provide power, USB currently remains the primary means of connecting mobile information devices, but wireless connections are likely to become more prevalent as wireless power transmission technology becomes more common.

In North America, satellite radio and hybrid digital (HD) radio are continuing to gain market share. In Europe, various national governments are promoting the transition to digital radio, and efforts to prepare for the reception of digital audio broadcasts (DAB) are gaining momentum. The rate of installation of devices capable of receiving such broadcasts is anticipated to increase. At the same time, the rising demand for display audio, particularly in North America and Europe, is leading to the growing popularity not only of its application to parking assistance, but also of the now standardized interconnectivity with smartphones. Display audio can also be used to receive internet radio or traffic information via smartphones, as well as to show screens from video streaming or other applications. Consequently, market share growth is predicted for display audio as a reasonably priced information and entertainment device. Car audio is expected to continue involving through interconnectivity with smartphones or portable devices.

2. 10. Safety devices

In 2015, there were 4,117 fatalities and 665,000 people injured in traffic accidents in Japan. While the number of injured people decreased, the number of fatalities increased for the first time in 15 years (4 extra fatalities). The rise in the accident of elderly people, which has high fatality rate is one of the causes of the increase in fatalities. In addition, a tragic bus accident causing many fatalities underscored the need for even further efforts to prevent traffic accidents.

These circumstances are leading to changes in regulations and vehicle assessments. Japanese regulations have made the installation of collision mitigation braking systems mandatory for heavy-duty vehicles (buses and trucks with a gross vehicle weight of 3.5 tons or higher) since 2014, and the mandatory installation of lane departure warning systems has also been decided and is scheduled to be gradually applied based on gross vehicle weight starting with new vehicles launched in November 2017. Active safety devices are expected to provide accident prevention benefits not only in heavy-duty vehicles, but also in ordinary vehicles, and the Japan New Car Assessment Program (JNCAP) is evaluating vehicle based on uniform criteria. The devices are evaluated in the active safety assessment category by the JNCAP, and vehicles that meet or exceed a given evaluation score are certified as an advanced safety vehicle plus (ASV+).

On an international level, excitement is bubbling over the realization of automated driving, which sets the reduction of traffic accidents as one of its goals. In Japan, the government's Strategic Innovation Promotion Program (SIP) has promoted the theme of automated driving since 2014, and has made plans for the development of more sophisticated map information (dynamic maps) and improved sensing capabilities of the environment around the vehicle, among others, as potential areas of collaboration. Development efforts to realize automated driving are also being pursued through, for example, automated driving field tests by various manufactures and universities. Given the call for advance safety functions that do not cause accidents as basics, automated driving is expected to tie into the development of even more sophisticated active safety systems.