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Electromobility Innovation Trends

IEEE VTS Motor Vehicles Challenge 2021

To encourage researchers and engineers expending efforts on systematic approaches for energy management strategies (EMS) for electrified vehicles, the IEEE Vehicular Technology Society (VTS) has organized Motor Vehicles Challenges since 2016. This year, the University of Sherbrooke, Québec, Canada, has been the technical sponsor of the IEEE VTS Motor Vehicles Challenge 2021, focusing on real-time force allocation strategies for a dual-motor, all-wheel-drive electric vehicle (EV), as can be seen in Figure 1 [1]. This was a very competitive challenge; we received 45 EMS from 21 teams from 11 countries. The two top-ranked strategies received the same best total score measured by the final state-of-charge (SOC) of the battery, considering the machines' torques and battery cell temperature constraints for a complete unknown driving cycle.

The next version of the IEEE VTS Motor Vehicles Challenge will focus on combining energy management and component sizing multiobjective optimization problems for a multisource EV (see Figure 2). The participants will design the hybridization of a battery and supercapacitor based on commercial vehicle and cell models. Then, they will develop the real-time EMS to minimize the objective function of battery SOC, supercapacitor charge-sustaining, battery cell current rms value, and its variations. The 2022 challenge will be technically sponsored by Hanoi University of Science and Technology, Hanoi, Vietnam (see Figure 2).

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Electromobility Innovation Rankings

The Center of Automotive Management (CAM) has analyzed the innovation of electromobility trends of 32 automakers based on 291 parameters [2]. The top innovator in battery EVs (BEVs) by far is Tesla. Tesla is followed by Volkswagen (VW) in second place, the Chinese manufacturer Build Your Dreams (BYD) in third place, and the Hyundai Group in fourth place. Geely, BAIC, and SAIC also made it into the top 10 of the most innovative BEV carmakers, marking them as leveraging the electromobility transformation. Chinese original equipment manufacturers (OEMs) do even better in this ranking, as presented in Table 1. The CAM research shows a big improvement for companies like Nio and Xpeng, even if they still land outside the top

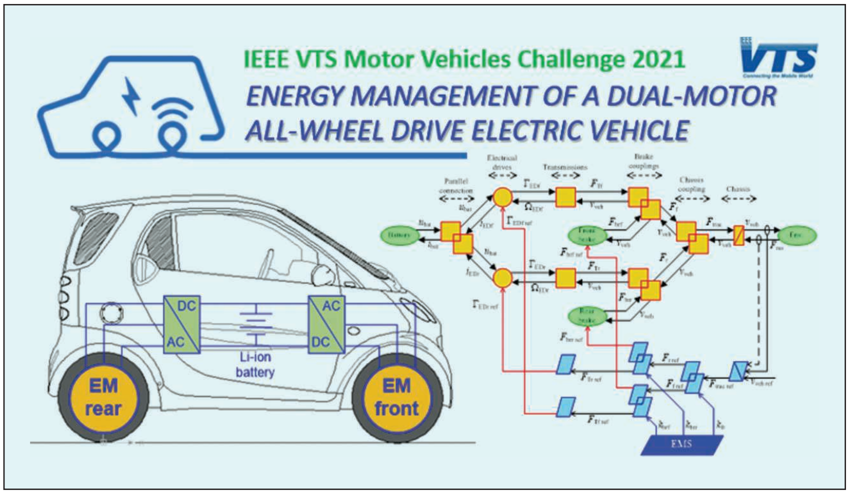

FIGURE 1 IEEE VTS Motor Vehicles Challenge 2021 [1]. (Source: https://oraprdnt.uqtr.uquebec.ca/pls/public/gscw031?owa_no_site=6410.)

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Many established carmakers have a lot of catching up to do in terms of electronics innovations.

10. Daimler and Bayerische Motoren Werke (BMW) follow in the rank middle, while Toyota, Honda, and Ford are responding more slowly. For electromobility innovation assessment, series-produced electric cars in the areas of range, consumption, and charging performance are analyzed.

Tesla increased its lead in 2020 by 45 index points thanks to strong innovations in the areas of range and charging performance and now presents a BEV innovation strength of 159.4 total index points. VW increased its score by 37 index points to 122.6 total points in contrast to the previous year. The reason for this score is high segment ranges and the charging performance of the VW ID.3 as well as other innovations from Porsche (Taycan) and Audi (e-tron). BYD makes a big leap of 23 index points to third place with 70 points, benefiting from innovations of the so-called BYD Han EV. Hyundai-Kia, after high growth in the previous year, only shows moderate gains in 2020 with a nine point jump to reach a total of 58.2 index points.

The CAM study suggests that automotive electronics is largely responsible for the innovation factor improvements. Despite high sales figures, the group of followers includes the Renault-Nissan-Mitsubishi alliance, which is still just ahead of General Motors (GM) in fifth place with 41.4 points. Geely made a jump forward in innovation, catapulting itself from 15th to seventh place, mainly thanks to innovations from its Volvo and Polestar subsidiaries. BAIC and PSA in eighth and ninth place, respectively, show only a low BEV innovation performance. Next year, the merger of PSA and Fiat Chrysler Automobiles (FCA) will surely change its ranking regarding electromobility innovation due to its recent unveiling of the Stellantis electrification plan. However, the Chinese SAIC group improved by 10 places and made it into the top 10 mainly thanks to the innovations of its Roewe brand with the Marvel X and ER6 models [2].

Many established carmakers have a lot of catching up to do in terms of electronics innovations, as they are making only slow progress in the transition to BEV models. These include the German carmakers Daimler and BMW, which only manage 11th and 13th place, respectively. While Daimler improved marginally compared to the previous year due to innovations in its EQC and EQV models (plus 11 points), BMW largely lacked innovations last year (only plus four points). Surprisingly, well-known carmakers such as Toyota and Honda are responding slowly in electromobility transition, reaching 23rd and 24th position, respectively,

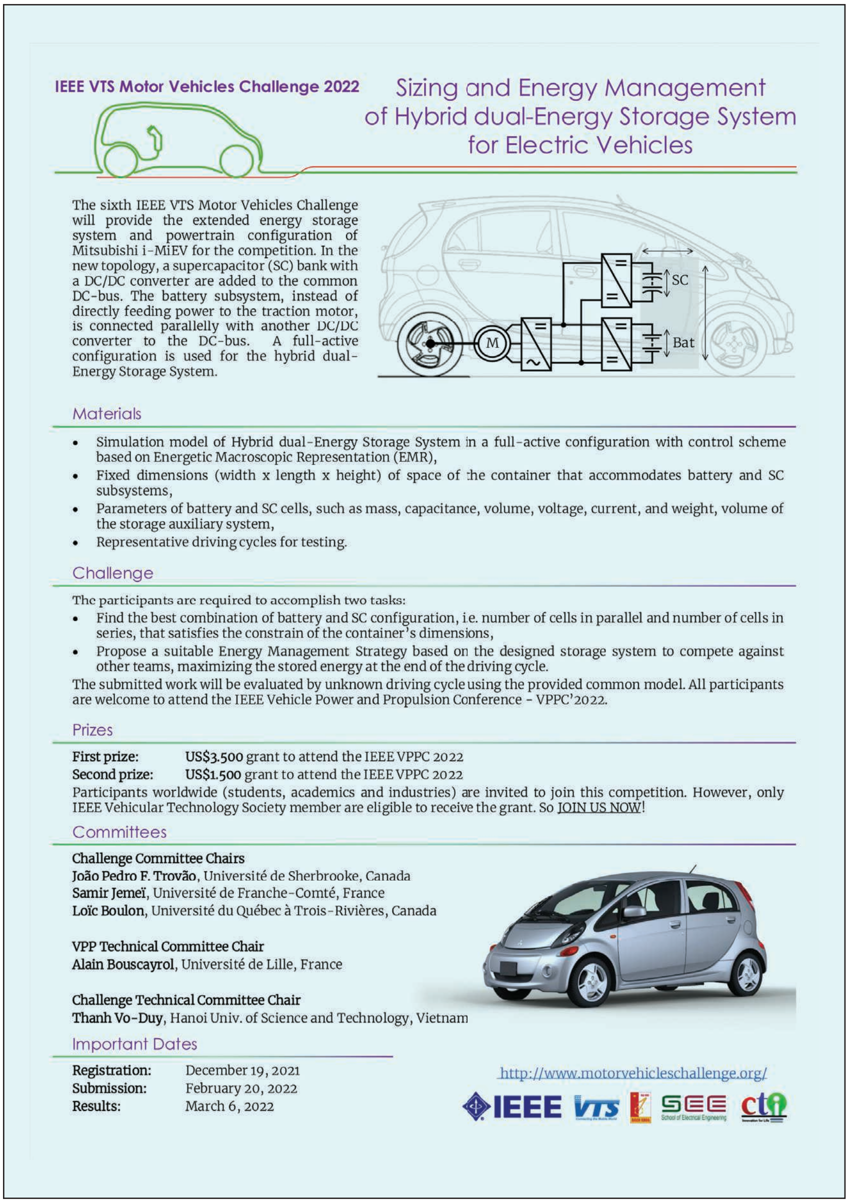

Figure 2 IEEE VTS Motor Vehicles Challenge 2022. (Source: IEEE VTS.)

as can be seen in Table 1 [2]. This indicates that considerable innovation momentum can be expected not only from Tesla but also from recent carmakers working on electric mobility such as Lucid Motors and the Chinese manufacturers Nio and Xpeng. But a high risk is assumed by the companies that are late to move forward electromobility. In terms of global sales of BEVs around the world, Tesla is leading the pack with double the sales of established carmaker VW, as presented in Figure 3.

The recently created carmaker group Stellantis moved to the sixth largest carmaker worldwide (behind the VW group, Toyota, the Renault-Nissan-Mitsubishi Alliance, GM, and the Hyundai-Kia group) because of the junction of FCA and PSA, who started the year with the revelation of their electrification plan promising models with a driving range of 800 km, as presented in [3]. This plan includes the first details of its electrification strategy for the next decade and promises specific platforms and new batteries with greater capacity. The strategy is different for Europe and North America and promises four specific platforms for electrified vehicles and new batteries for a driving range of more than 800 km.

Four platforms for EVs are planned and ongoing: eCMP (second-generation) presented in Figure 4; STLA Medium; STLA Large; and STLA Frame. For smaller cars, Stellantis will continue to use the well-known eCMP (the platform used for the Peugeot e-2008, Peugeot e-208, or Opel Corsa-e) as presented in Figure 4, but a second generation will arrive soon to serve as a multienergy platform and full-electric traction for the end of 2022 and will be used until 2026. At that time, it will be replaced by a new STLA Small platform (A, B, and C segments) with a targeted autonomy over 500 km [3].

For the second half of 2023, the STLA Medium platform is planned, aimed at medium cars (C and D segments). This platform will replace the well-known EMP2, which allows

TABLE 1 *Electromobility innovation rankings for 2020/2021 (based on [2]).*

Rank	Previous Year	Carmarker	Index Points 2020	Trends for 2021
1	*1*	Tesla	159.4	↑↑
2	*2*	VW	122.6	↑↑
3	*4*	BYD	70	→
4	*3*	Hyundai-Kia	58.2	→
5	*5*	Renault-Nissan-Mitsubishi	41.4	↑
6	*8*	GM	40.2	↑
7	*15*	Geely (Volvo-Polestar)	36.6	→
8	*6*	BAIC	34.4	↑
9	*9*	PSA	31.9	→
10	*20*	SAIC	31.4	→
11	*10*	Daimler	26	→
12	*17*	GreatWall	24.3	↑↑
13	*11*	BMW	18.8	→
14	*25*	Fiat Chrysler	17.3	→
15	*14*	Tata	15.7	↑
16	*13*	Nissan	13.2	→
17	*28*	Ford	12.8	→
18	*18*	Nio	9.2	→
19	*29*	Mazda	7.8	→
20	—	Xiaopeng	7.2	→
21	—	Airways	5.6	→
22	*26*	Toyota	5.3	→
23	—	Honda	2.8	→

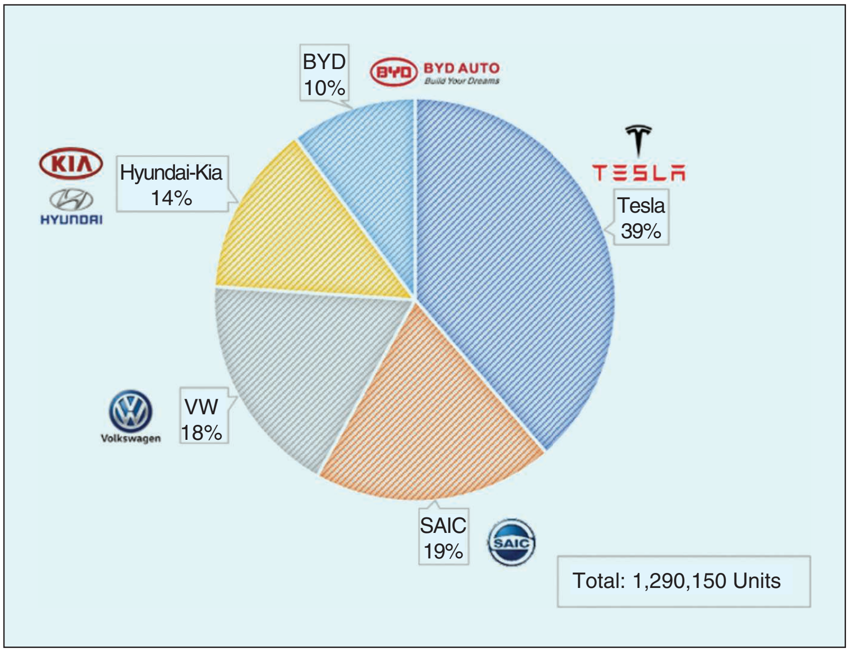

FIGURE 3 Global sales of battery EVs, 2020 [2]. (Source: CAM Electromobility Report data.)

CALLED THE MAGNA ETELLIGENTREACH, IT FEATURES INTELLIGENT OPERATING SOFTWARE AND CONTROLS.

only the plug-in hybrid powertrain; despite the new name, it is effectively the eVMP that PSA had already announced. This platform promises a range of up to 700 km, and the first model to use it will be the successor to the Peugeot 3008 [3]. For larger vehicles (D and E segments), Stellantis will have a STLA Large platform, which promises to provide a driving range of greater than 800 km [3]. Finally, the STLA Frame platform will serve as a basis for larger SUV and pickup group brands, such as Ram, from 2024. For this platform we can expect driving ranges of over 500 km.

The electrification path has long been defined for Stellantis, and more than 400,000 electrified cars (plug-in hybrids and 100% electric) were sold by the group in the first trimester of 2021. Projected sales of 38% of electrified vehicles sales in Europe by the end of 2025 from Stellantis and a 70% share by 2030 are anticipated with these new platforms. This will be possible thanks to internally introduced dynamics and joint ventures with Nidec for electric motors and with Total-Saft for batteries. The relationship with the latter resulted in the Automotive Cells Company, which will have two battery plants in Europe with potential capacity of 32 GWh (each) in 2030 [3].

The issue of CO_2 targets that need to be met and the high costs involved in not achieving them is one of the threats to automotive companies. But the newly unveiled strategy of electrification by Stellantis will allow the group to comply with the required numbers and avoid high fines. In recent years, FCA has spent hundreds of millions of euros (1,500 million from 2018 to 2020 and 700 million in 2020) buying regulatory credits in the United States and Europe to avoid fines for noncompliance with CO_2 goal levels [3].

Magna BEV and PHEV Platforms

Magna is one of the biggest car companies that you probably never heard of. It makes its living developing and building automobiles for other companies such as BMW, Daimler, Jaguar Land Rover, and Toyota [4]. The biggest Magna claim is innovation and manufacturing competencies based on a comprehensive understanding of what the vehicle is. The company offers modular solutions for every system and parts as well as complete vehicle assembly services.

Actually, the largest car companies, like VW and GM, design their own EV platforms; however, for smaller companies like Mitsubishi, Subaru, and Mazda as well as for the many car companies springing up everywhere with the move toward electric mobility, the cost of developing an electric car platform from scratch can be prohibitive.

Magna unveiled details of two new platforms developed in house: one for plug-in hybrid EV (PHEVs) and one for 100% BEVs [4]. Called Magna EtelligentEco, the new company's plug-in hybrid platform features cloud-based connectivity that can guide drivers to charging stations where electricity from renewable sources is available. It also analyzes the route ahead and makes recommendations on how to lower emissions based on traffic, terrain, and other factors.

Magna says the platform can reduce greenhouse gas emissions by as much as 38%. Recent studies in Europe suggest that some plug-in cars actually pollute more than conventional cars, so it will be interesting to learn more about this platform and emission calculation. The Magna EtelligentEco platform uses a 120-kW motor and a hybrid transmission and will have an all-electric range of 100 km for this plug-in platform.

The second Magna platform is for BEVs only and comes with two electric motors, one driving the rear wheels and the other driving the front wheels. Called the Magna EtelligentReach, it features intelligent operating software and controls. The advanced technology now delivers a significant range increase and further enhanced driving dynamics. In fact, with innovation upgrades to the software and hardware, the range is extended another 20%, or to more than 145 km in total when compared to existing same-segment vehicles in production.

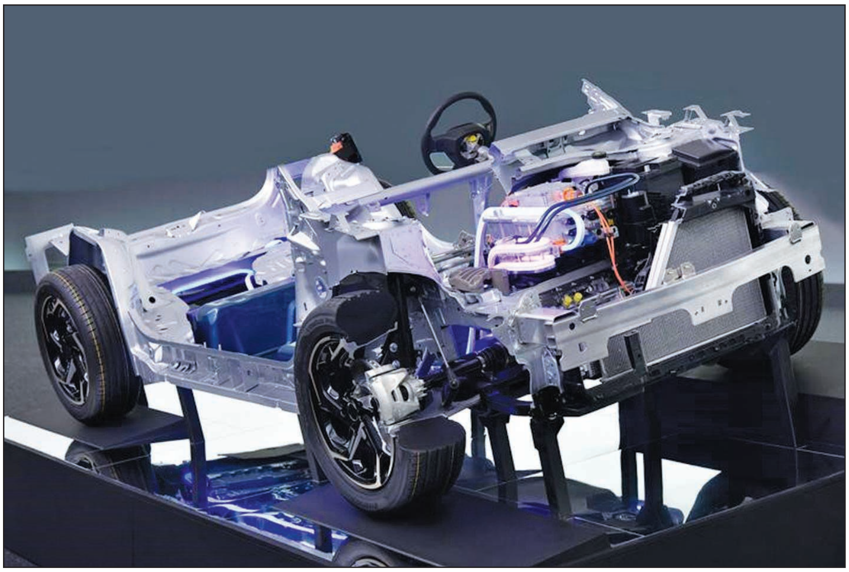

FIGURE 4 The Stellantis eCMP platform. (Source: Stellantis; used with permission.)

This latest BEV platform includes an advanced decoupling function, inverters with silicon carbide (SiC) technology, and further-improved operating software, which results in advancements that will benefit all of Magna electric drive solutions and next-generation hybrid drives.

As carmakers continue to progress toward a zero-emissions future, Magna is proposing itself as a supplier partner that can provide new and innovative products to help makers in their journey to full electromobility. Magna offers a unique expertise based on a scalable building-block technology approach to match the demand when its costumers need a complete electrified powertrain solution integrating all subsystems and parts.

Recently, some information has been released to the public regarding the Fisker Ocean electric SUV model that will be entirely built by Magna. An agreement has been made with Foxconn to build a second Fisker model based on Magna platforms.

MAHLE Magnet-Free Electric Motor

German automotive parts manufacturer MAHLE has developed a new highly efficient magnet-free induction motor that is more environmentally friendly to produce, cheaper to manufacture than comparable motors, and maintenance-free, as explained in the company press release [5].

The company says it has combined the strengths of various electric motor concepts in a single product, allowing for an efficiency above 95% at almost all operating points, a level that has been achieved only in Formula E racing cars.

MAHLE explains that its new kind of magnet-free electric motor does not require rare-earth elements. This makes production better for the environment and also brings advantages in terms of costs and resource security and supply chains.

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The new motor uses a fine-tuned design to generate torque via contactless power transmission, making it wear-free and highly efficient at high speeds. When in use, a wireless transmitter sends an alternating electric current into the rotor. This induces a current in a receiving electrode, which in turn charges wound-copper magnet coils to produce an electromagnetic field that spins the coils and generates torque [5].

These magnetic coils replace traditional EV motors' permanent magnets, typically made of neodymium-boron-iron, samarium-cobalt, or ferrite. Where these are typically placed in an EV motor, MAHLE and other designers' induction motors leave an air gap to prevent wear. MAHLE also highlights the fact that its design is easily scalable and can be used in anything from subcompact to commercial vehicles. Dispensing with magnets and therefore the use of rare-earth elements offers great potential not only from a geopolitical perspective but also with respect to the responsible use of natural resources.

To come up with the design, MAHLE says it used a state-of-the-art simulation process that allowed it to adjust and combine the parameters of different motor designs incrementally to settle on the optimal solution. The company says this new method allows it to quickly create the necessary technical conditions to advance electromobility in a sustainable manner worldwide.

Although the new motor design (see Figure 5) was conceived using the very latest simulation processes, the inception of induction motors dates back to the 19th century, when they were invented by Nikola Tesla. A new EV development, EV-charging roads and highways, similarly builds on the inventor's early work on alternating currents.

The recent boom in EV uptake has seen carmakers outside China working hard to develop electric motors that do not use permanent magnets. This results from the fact that such magnets require rare-earth metals, the mining of which is usually bad for the environment.

What is more, the materials are largely mined and processed in China, giving Chinese EV automakers the edge when it comes to traditional EV motors. Over 90% of the world's rare-earth elements currently come from China.

OCTOPUS Motors

Recently, Bentley also unveiled an electric motor design that does not rely on rare-earth magnets. The company revealed the motor last year in its bid to lead the charge in sustainable luxury mobility [6].

The new Bentley electric motor, based on the OCTOPUS (Optimized Components, Test, and simulatiOn toolkits for Powertrains Integrating Ultrahigh-speed motor Solutions) project, delivered a technological breakthrough in electric drive systems for high-performance vehicles. The results are built on U.K. electronics research projects, and the resulting electric drive system exceeded the latest permanent

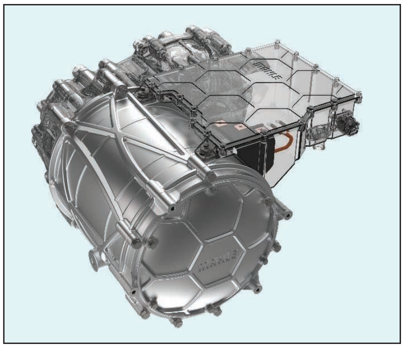

FIGURE 5 The new traction motor from MAHLE is wear-free, compact, and not dependent on rare-earth elements [5]. (Source: mahle.com; used with permission.)

A core technology here is the lithium-ion battery and, essentially, electronic battery management systems adjusted to the battery packs.

magnet motor performance while simultaneously removing the need for both rare-earth magnets and copper windings, delivering a package that is both cost-effective and recyclable at its end of life [6].

OCTOPUS project results will take this leading-edge motor, power electronics, and packaging transmission design and add next-generation materials, manufacturing processes, simulation, and test cycles to deliver a full e-axle powertrain with unique levels of integration and revolutionary performance characteristics suitable for real-world application by 2026 (see Figure 6).

Hella Dual-Voltage BMS

OEMs like Hella are moving quickly to enrich their electromobility portfolio due to the disproportionate growth for all-EVs and partially electrified drive systems, such as mild hybrids, in the coming years. A core technology here is the lithium-ion battery and, essentially, electronic battery management systems (BMS) adjusted to the battery packs. The parts supplier Hella is completing its product portfolio with a 48-V line. The new 48-V system was due to go into series production this summer in collaboration with a Chinese cell producer and will include an OEM battery pack consisting of battery cells and the associated Hella BMS [7]. During development, the company leveraged its expertise in high-voltage battery electronics. Past experiences from Hella in producing high-voltage BMS for BEVs as well as full hybrids and rechargeable devices since 2016 are very relevant to this move.

This Hella know-how is transferred to mild hybrids requirements. The 48-V BMS intends to make a fundamental contribution to achieving a CO_2 emission-reduction functionality for a moderate hybrid usage. This includes energy recovery during braking (regeneration) and stronger acceleration (boost) as well as cruising at idle with the engine off.

In the low-voltage range, Hella is also developing a BMS for 12-V applications. Here, battery production is planned in cooperation with another cell producer. The 12-V BMS also can be used in EVs, in addition to the emergency power supply, for example when the vehicle is stationary or parked, and it mainly serves as a redundant power supply. On the other hand, it can also be installed in vehicles with conventional internal combustion engines, where it can provide a potential technical solution for the possible banning of the classic lead-acid batteries.

OSRAM Continental Takes Automotive Lighting Field

Another parts supplier, OSRAM Continental, has just introduced an exchangeable LED module for use in vehicle headlights. This exchangeable engine light simplifies the integration of LED lighting solutions in entry-level vehicle classes and facilitates the replacement of defective LED lighting, which was previously possible only with a great deal of effort [8].

At a time when traditional headlamp technologies are gradually being replaced by LED systems, carmakers are facing high cost pressures. With the eXchangeable Light Engine (see Figure 7), OSRAM Continental is meeting this challenge by making LED lighting available even for entry-level models and basic equipment. In this way, the company wants to further promote the overarching transition to LED as standard lighting in the market.

The use of the eXchangeable Light Engine for all vehicle classes is made possible thanks to a modular and scalable product approach with three power variants for flexible headlamp design. In addition, the highly efficient thermal design contributes to the best possible system integration.

In addition to these benefits for the OEM, the eXchangeable Light Engine paves the way for drivers to have access to the best possible automotive lighting even in basic equipment, offering them gains in light quality, safety, and comfort. The previous lack of reparability had been met

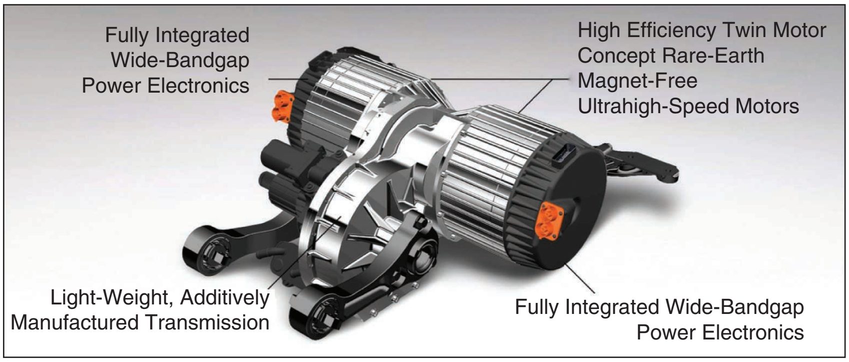

Figure 6 The Bentley motor system, based on the OCTOPUS project [6]. (Source: bentleymedia.com; used with permission.)

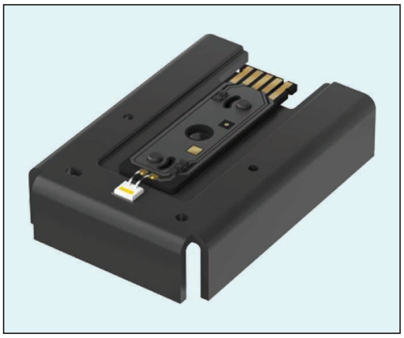

Figure 7 The OSRAM Continental eXchangeable Light Engine. (Source: osram-continental.com; used with permission.)

with criticism among consumer organizations [8].

One Electric Scooter Every Two Seconds

The largest electric scooter factory of in the world is now open. This is the new OLA Electric factory in the southwest of Bangalore, India, with an estimated 10 million units being released annually, which means that every two seconds a new electric scooter ready to be sold [9].

OLA Electric wants to enter the two-wheel battery vehicle market by the front door, with a plan to extend its work operation to cars in the next two years. The new factory will be not only the largest but also the most advanced and sustainable factory in the world.

The approach used intends to take advantage of the scale effect and thus reduce costs to be able to compete with gasoline counterparts. This is based on the popularity of two-wheel transport in India, but consumers are more sensitive to price than to air quality. The OLA Electric scooter project is presented in Figure 8.

OLA Electric plans a self-contained project with fine control of all project phases, from motor design and production to the cells for its packs; development of its own software (more than 1,000 engineers are working on this development); and charging solutions and user-friendly stations for swapping battery packs. The OLA Electric factory will have 10 production lines and 3,000 robots controlled by artificial intelligence for maximum precision and manufacturing optimization. OLA Electric plans to hire 10,000 employees in 2022 and reach production of 10 million of scooters/year [8].

Nissan Accelerates Development and Testing of Engine Control Software

By 2022, the Nissan Motor Corporation plans to renew all core models and introduce 20 models to strengthen its product lineup centered on

NISSAN USES SIMULATIONS WITH A PLANT MODEL TO EVALUATE ALL SOFTWARE COMPONENTS IN THE APPLICATION LAYER CREATED IN SIMULINK.

Nissan Intelligent Mobility. Nissan engineers are using model-based design with MATLAB and Simulink to reduce development and verification times for their engine control software. Nissan uses simulations with a plant model to evaluate all software components (SW-C) in the application layer created in Simulink. To be suitable for a large number of engine variants in the company product line, Nissan engineers have established a standardized workflow in which they use Simulink and Powertrain Blockset to develop engine model variants and perform model-in-the-loop (MiL) and hardware-in-the-loop (HiL) tests. Nissan plans to use the same model for both MiL and HiL testing, greatly reducing the effort required and accelerating development [10].

Nissan engine control software combines nearly 1,500 SW-Cs. Nissan engineers use simulation to evaluate each of these SW-Cs for multiple engines with variations including displacement, number and arrangement of cylinders, and maximum torque. In the past, engineers tuned the parameters for engine model variants manually. Simulations using the models imposed heavy computational requests, leading to impracticably long simulation hours. Simpler models could be simulated faster but were less accurate. Because they used different toolsets for MiL and HiL testing, Nissan teams needed to create an entirely new plant model to conduct real-time HiL tests. To eliminate duplicated effort and shorten testing schedules, Nissan wanted to use the same plant models for both MiL and HiL tests.

To do so, Nissan uses model-based design with Simulink and Powertrain Blockset to develop and test application software (ASW) for powertrain control, as presented in Figure 9. The ASW contains some individual SW-Cs from suppliers. Nissan engineers use the spark-ignition engine dynamometer reference application from Powertrain Blockset as the basis for

FIGURE 8 OLA Electric is to launch its electric two-wheeler. (Source: OLA Electric; used with permission.)

their engine plant model. They use the resize engine and recalibrate controller feature to automatically resize the engine model and adjust the calibration parameters based on settings such as the number of cylinders and engine displacement. The engineers make further modifications to the model as needed. To validate the engine model, they execute built-in tests from the reference application and check the simulated engine torque and other performance metrics. They then create a system model in Simulink by combining the validated engine model with a controller model, a transmission model, and a simple vehicle model.

Using an automated testing framework developed in MATLAB, the engineers conduct MiL tests to ensure that the controller model meets specifications. This framework sets tests conditions, initiates simulations, and produces graphs for visualizing results. In preparation for HiL testing, the team generates code from the engine model with Simulink Coder and deploys it to dSPACE real-time prototyping. They run the same test cases used in MiL for the real-time HiL setup. Nissan has already used this workflow to evaluate engine control software for production vehicles, and the company plans to use it to develop plant models for HiL and MiL testing of engine variants in upcoming models.

As a main result, models for engine variants are created in hours, not days. Nissan has accelerated the development of ASW while ensuring quality. Code development costs were cut by two-thirds. Also, by modeling the control ASW in Simulink and using the model as an executable specification, it has eliminated misunderstandings that can normally occur between OEMs and suppliers. Furthermore, by generating code from these models, the company has easily reduced the bugs and human errors that come with handcoding. These improvements enabled Nissan to cut code development costs by roughly two-thirds and shorten development times. HiL preparation time was significantly reduced. With Simulink and Powertrain Blockset, Nissan is using the same model for MiL and HiL tests. Having a common set of test cases, plant models, and tools for both environments has reduced the engineering hours required for HiL testing from one week to one day. That is how Nissan engineers are using MATLAB/Simulink model-based design.

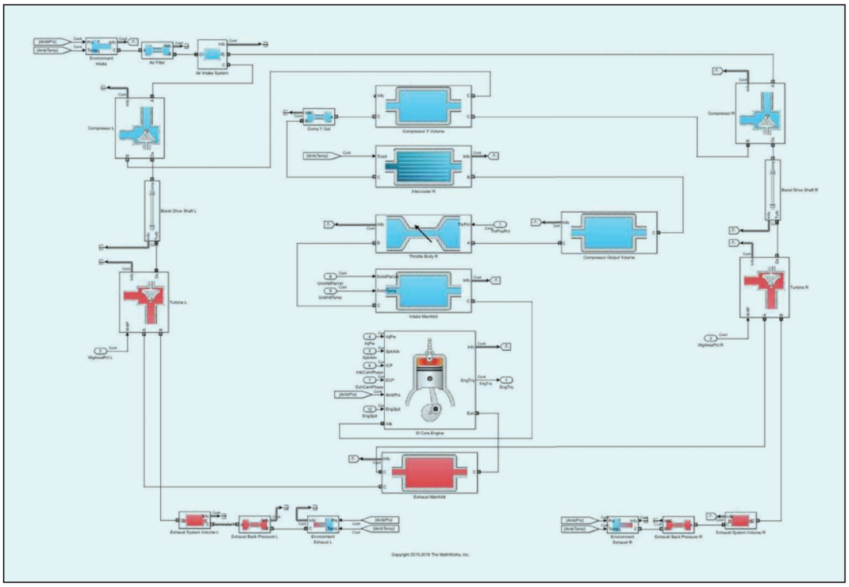

FIGURE 9 The MATLAB/Simulink Powertrain Blockset dynamic engine model [10]. (Source: matworks.com; used with permission.)

Chariot Motor E-Bus UC Technology

The Chariot Motors pure ultracapacitor (UC) city electric bus (e-bus) featured Aowei's (Shanghai Aowei Technology Development Co., Ltd.) latest and most advanced UC. The Higer model bus from Chariot Motors is assembled in its world-leading facilities. The company's urban transportation UC Chariot e-bus is a 12-m low-floor city bus, as presented in Figure 10. It has 30-plus two-seat places, room for a wheelchair, and standing room for 58 passengers, plus a disability ramp. It complies with European homologation certifications, a strict market requirement, including the ECE R100 energy storage device standard [11].

The UC offers advantages over conventional diesel traction. It cuts operational costs by 80% per kilometer. Without a reciprocating engine and transmission and factoring in maintenance, it therefore costs 30% less compared to diesel counterparts [11].

This summer, 30 brand new Chariot-Higer e-buses will be on the streets of the Bulgarian capital, Sofia. Operated by Stolichen Elektrotransport, they will replace some of the city's diesel buses to reduce the emissions due to public transport operations. Alongside the 15 e-buses already delivered by Chariot Motors to Sofia, these new ones will further improve city air quality. The e-buses with UC technology do not produce NOx, CO_2, or particulate emissions locally.

Powered by industry-leading innovative UCs, these UC e-buses do not need long overnight charging. Their final fast charge from the previous day is sufficient to run the e-bus the next morning. Frequent charge/discharge cycles do not affect UC longevity. UC has proved to be robust, environmentally friendly, and safer, outperforming batteries on these indicators. They are nonflammable and in harsh conditions retain performance in temperatures between –40 and 60 °C. They have no harmful or toxic components, presenting no pollution hazards and no hidden end-of-life disposal costs.

Such e-buses have already proven their success in other cities, including Gabrovo, Belgrade, Tel Aviv, Graz, La Spezia, Torino, Aalborg, and other European cities.

Sofia has steep clean air ambitions. The city wants to halve legacy fossil-fuel public transport buses by 2030 and be rid of them by 2050, as the Bulgarian integrated transport strategy has a goal for CO_2-free urban logistics by 2030.

Sofia transport users are getting used to the comfort of modern, sustainable, zero-emission UC e-buses. The vehicles offer low floors, air conditioning, Wi-Fi, and USB ports [11].

In 2016, the first five Chariot UC e-buses were put into commercial operation in Belgrade. Since then, they have been operating daily between 5:30 a.m. and 11 p.m. in temperatures between –14 C and 40 °C. The annual mileage is above 62,000 km per e-bus [11].

In the first year of operation, Chariot e-buses offered 97.5% availability, higher than diesel or compressed natural gas buses and even trolleybuses, according to the manufacturer.

Chariot Motors was established in 2009 with the sole purpose to design, develop, and bring into commercial operation one-of-a-kind UC-based e-buses in continental Europe and Israel. Chariot Motors contributes to the transition toward green public transportation, offering fully electric zero-emission nonpolluting e-buses.

Chariot Motors plans to expand the market for e-buses and Aowei UC technology for different applications, such as trolleys, trams, garbage and heavy trucks, ferries, fuel cells, and energy storage for renewable technologies. Chariot Motors has a long-term partnership with Aowei and is its exclusive representative for the European continent.

FIGURE 10 A Chariot Motors pure UC city e-bus and its fast charging system [11]. (Source: chariot-electricbus.com; used with permission.)

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