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# "Highly integrated Axle Drive for EV traction and charging"

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**Summary**

Electric vehicles and plugin hybrids need high-voltage drive solutions in order to drive on electricity only. In China, where electric driving is being strongly promoted at the large-scale production level, there is strong pressure to implement this challenging goal in the shortest possible time. Continental has analyzed the requirements and, on this basis, developed a complete electric powertrain module with a high power to size ratio. It will go into production in China in 2019.

*Keywords: electric drive, EV (electric vehicle), PHEV (plug in hybrid electric vehicle), efficiency*

## 1 Highly integrated Axle Drive for EV traction and charging

### 1.1 Requirements of electrification in China

After a latency period that was clearly underestimated in early forecasts, the electrification of vehicle drives is now on the cusp of reaching the mass market. While series breakthrough in Europe is marked by mild hybrids with 48 V technology and unit sales in the all-electric segment have not yet begun to grow, the world's biggest vehicle market is already taking the next step. The political and regulatory strategy in China will see electric driving play an important part in improving air quality in major Chinese cities. In addition to solutions for premium class cars and systems for compact vehicles, one key challenge is to manage unit sales in the mid-size class.

In this segment, electric driving (electric vehicles, EV, and plugin hybrid vehicles, PHEV) requires optimum performance in the range of 100 to 150 kW and a torque of about 2,500 to 3,000 Nm at the drive axle (200 to 300 Nm electric) in order to enable comfortable mobility and agility. Compact vehicles, by contrast, can be motorized with systems for 50 to 100 kW, while larger models require 150 to 250 kW. This range of required power results in the three-level platform approach that is being developed by Continental. Specifically in relation to China, the mid-size segment was chosen as the top priority. Given the combination of vehicle mass (around two metric tons), the required power and the tight economic margins associated with this mass-production segment, electrification involves considerable challenges here. In terms of vehicle integration, electrification also needs to be compact and it must not add too much extra weight, in order to keep the total mass as low as possible.

This logic leads to a high power to size ratio, which in turn requires a high degree of integration as a means of optimizing the installation space, mass and number of components in equal measure. In addition, a complete module reduces the effort of vehicle integration. At the 2015 IAA, Continental presented an initial preliminary version of the powertrain platform under development. This platform with three power classes is called the Electric Machine with Reducer (EMR). This powertrain module also includes an inverter and converter. By integrating the electric motor, transmission and power electronics, it was possible to omit many components such as connectors, cables, and hydraulic connections. Considerable cost savings were achieved as a result, while the weight of the drive at that stage of development was reduced by approximately 15% compared to a discrete design. The third generation of the electrical final drive, the EMR3, was developed on the basis of this concept. The first production ramp-up of this model is planned in China for 2019.

## 1.2 Scope and characteristics of EMR3

Typically, electric high-voltage powertrains (currently up to 450 V, up to 850 V in the future) are currently designed discretely; in other words, the individual key components – the electric motor, power electronics and transmission (and the battery) – are integrated individually and can be procured from different sources. Of course, this individual integration also involves a corresponding number of plug-in connections and high-voltage cable sections. This also means that OEMs, in their capacity as integrators, must themselves validate the interaction between individual components.

The EMR3 water-cooled electrical final drive takes a different approach. Here, all the components of the drive are integrated into a single module. **FIGURE 1** shows the state of development at the start of 2017, with the example of power class 2 with 100 to 150 kW output. The permanently excited synchronous motor (PSM) is closely connected to the higher-level power electronics and the high-voltage connections and the reducer integrated on the face. The space-saving arrangement of the original individual components around the electric motor's drive axle reduces the required installation space compared to individual integration plus cabling. The housing of the unit can be scaled in length and is made of injection-molded aluminum.

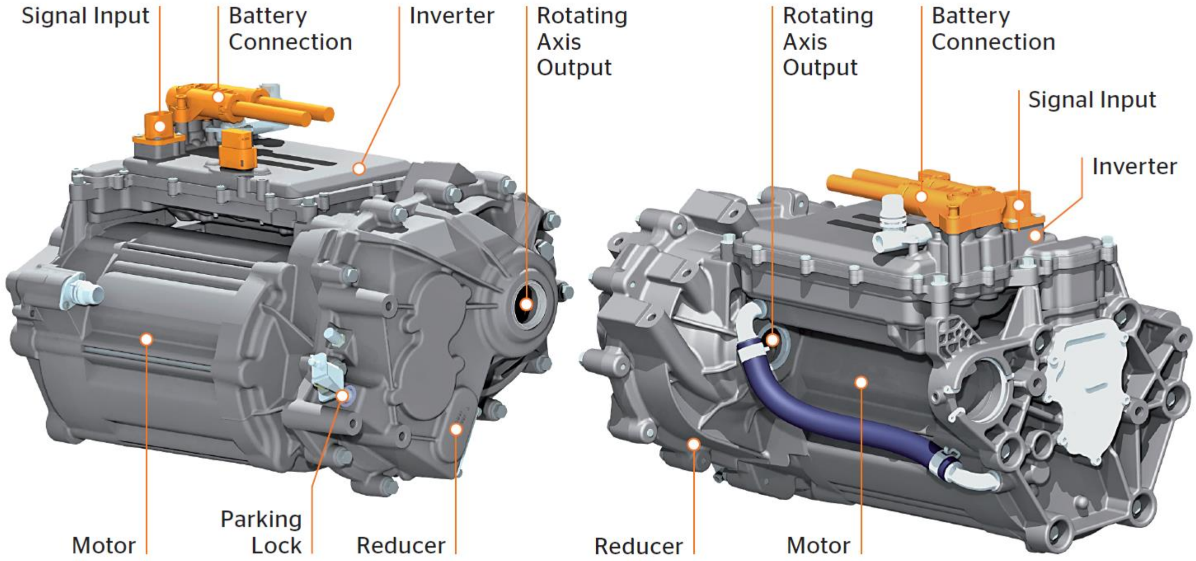


Figure1: Highly integrated electric powertrain EMR3 in power class 2 (100 to 150 kW)

At the level of the PSM motor, the powertrain module benefits from the compact inner design with specially formed neodymium-iron-boron permanent magnets (NdFeB), a small air gap between the rotor and stator, and a high copper filling factor. The PSM technology was chosen because it is the most efficient motor technology for the mid-size power class aimed at here. The stator's outside diameter is just 190 mm. The efficiency of the electric motor is 95% in by far the largest part of its operating map. The rotor is cooled by a flow of air, which transports away the heat from the stator via the cooling water channels.

At the level of the power electronics, the small dimensions (just four liters volume) are due to the high maturity level of the third generation of Continental's power electronics, which are already used in production. The changeover to sintering technology made a significant contribution to the efficiency combined with compact dimensions. Using the sintering method to attach the components enables higher operating temperatures, which allows higher currents for the same dimensions because the thermal bonding of the integrated circuits (ICs) is better. At the same time, the service life of the electronics increases by a factor of ten. The power electronics unit in FIGURE 1 includes an inverter. As the core inverter module was already qualified and validated for production in a hybrid vehicle in 2016, it and the software basic functions form a cost-effective re-use basis for use in the electrical final drive. Compared to the first generation of power electronics, the third generation now used in the EMR3 has six times the performance at a third less weight. At the same time, the cost per kW has fallen. The high level of maturity of the power electronics can also be seen in the fact that the inverter provides high currents despite its compact dimensions, and with a high degree of efficiency.

The reduction gear was developed specifically for this application in cooperation with the Swiss transmission specialists Oerlikon. The reduction is provided by a two-stage spur gear transmission with slanted toothing. The transmission housing forms a single unit together with the motor housing. Just like the overall module, the transmission will also be manufactured locally in China at our partner’s site.

The EMR3 also includes an increasingly popular function: an electrically operated parking brake to hold the vehicle in place when at a standstill. FIGURE 2 provides an impression of advances in integration, from the preliminary version of 2015 to today’s third generation. In this even more compact design, a further 20% weight was saved together with almost a third of costs.

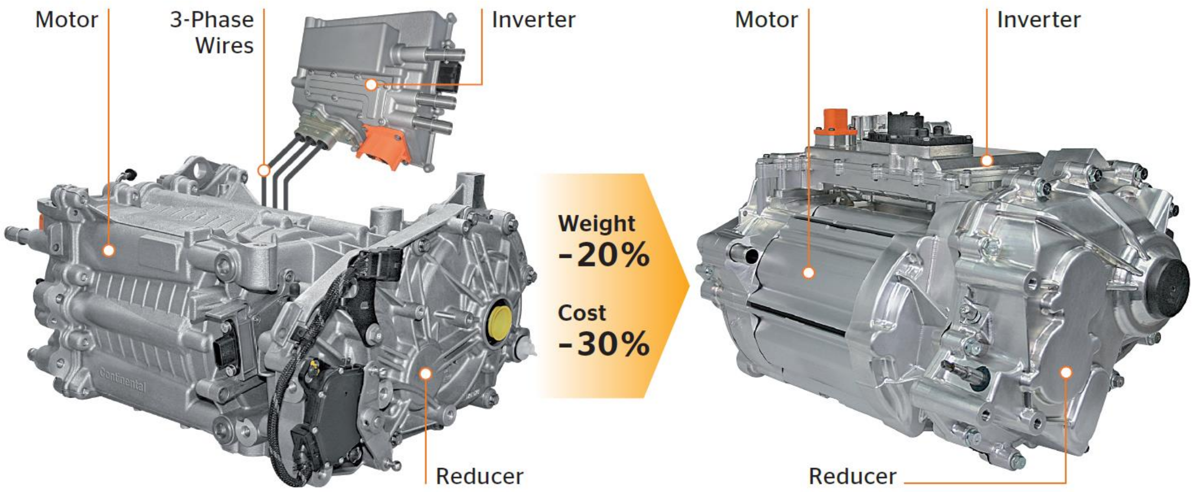


Figure2: Since 2015, increased integration has enabled further weight and cost savings

## 1.3 Scalability of the module

In order to provide scalability within the power class presented here (100 to 150 kW), the rotor and stator length is optionally 125 mm or 225 mm. In addition to scaling the power by means of the installed length of stator and rotor, it can also be scaled by the size of the inverter current. FIGURE 3 shows the key motor parameters. The average weight of power class 2 is just 75 kg (with 175 mm rotor/stator active length). The maximum currents in the power electronics are currently 450 A. The EMR3 final drive provides an average maximum of 270 Nm electric torque (between 190 and 400 Nm in the scaling range). The electric motor is designed for a maximum speed of 14,000 rpm. In short-time duty (10 s), the drive can electrically outputted between 100 kW and 150 kW at up to 400 Nm. Its continuous output is between 40 kW and 70 kW. The transmission ratio is 9.3. It can be defined in the range between 7.5 and 12.5 without changing the transmission housing. The overall module measures just 400 x 500 x 320 mm (for 175 mm rotor/stator), making it only marginally larger than the on-board luggage allowance on many flight. One of the key benefits to this high degree of integration is the combination of compact dimensions and high power output. When the electric powertrain is applied to a vehicle, the integration work is reduced essentially to adjusting the holding points and the position of the cooling water connections.

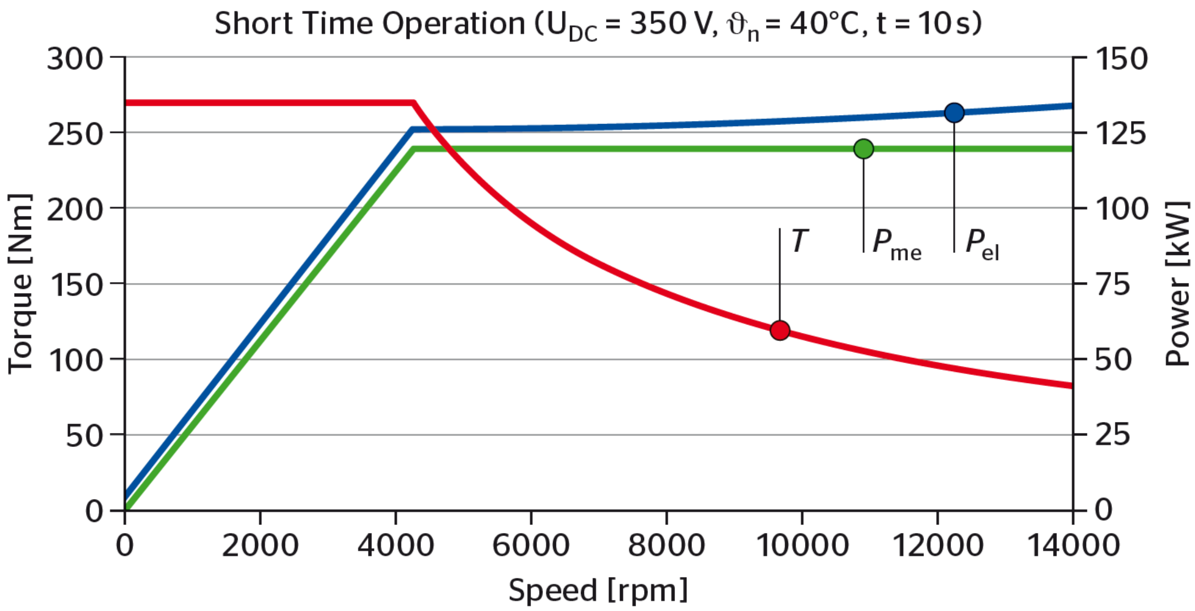


Figure3: Characteristics of the PSM machine

## 1.4 Operating characteristics

In an electric vehicle, the noise characteristics (noise, vibration, harshness, NVH) of the drive play a major role as there is no combustion engine noise to drown out undesired noise components. The same applies to PHEV during electric driving. All of Continental's previous experience of production, development and design of electric mass-produced drives went into the development of the EMR3; as a result, the integrated electric powertrain is not only ultra-compact, it is also low-noise and, above all, largely free of undesired noise components. Another important factor is electromagnetic compatibility.

## 1.5 Summary and outlook

The highly integrated EMR3 electrical final drive in the medium power level (platform class 2) was initially developed specifically for the requirements of vehicle motors in the mid-size class. The exceptionally compact module with a high power to size ratio contains the entire electric powertrain, and it can be integrated into an electric vehicle with minimal effort. The ready-to-install validated module also provides a new, cost-effective dimension to high-voltage electrification, thanks to its high degree of integration and its re-use strategy.

One final drive can be used to map a variety of power classes in a single module, thanks to scaling of the electric motor length, scaling of the maximum currents in the power electronics, and scaling of the transmission ratio. Continental will expand this platform principle to additional power classes in the future in order to further promote electrification.

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Hartmut Schneeweiss is working for Conti Temic microelectronic GmbH since 2012. His function is Head of Engineering Center Mechanical Engineering in the Hybrid Electric Vehicle (HEV) Business Unit at Continental Berlin. Overall responsible for development and design of electric motors in the field of hybrid and electric vehicles.