# ELECTRIFIED

## Testing on the Electric Motor Test Bench

____ To transform powertrain concepts from the design and simulation phases into reality, comprehensive testing is indispensable. In particular, testing an electric motor and interpreting the results represent a major challenge. An electric powertrain offers many advantages, but also a few special characteristics that require keen attention from engineers. Test benches at Porsche Engineering enable complex testing and detailed evaluations that are important for the development process.

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*Photos: Jörg Eberl*

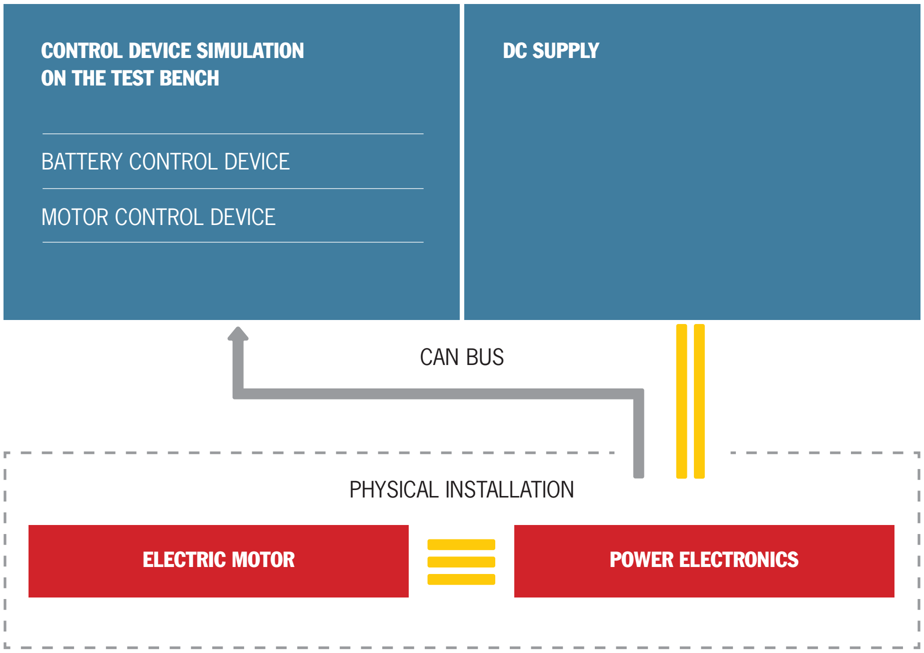
Once the design and simulation phases for an electric motor are complete, a model is built and put through its paces on the electric motor test bench. In the course of testing, theory is tested against reality, which requires special expertise on the part of the engineers. Above all this phase is concerned with ensuring that the motor fulfills the customer's requirements. Testing on the test bench is a part of every phase of the development of an electric motor, from the concept to series production. Before the machine can be measured, however, the application engineer must bring it to life.

### Application

The application engineer enables the communication or interaction between the electric motor and the power electronics. These two components must first be coordinated with each other. A test bench offers two possible options for this: the electric motor can either be operated with a universal inverter or the inverter to be used later in the vehicle. If multiple motors are operated with the same universal inverter, comparing the test series reveals differences between the motor variants. Universal inverters are often significantly more powerful than the unit planned for the series. They can thus push the motor to its physical limits and enable a precise estimate of its performance threshold. By contrast, using power electronics from the later powertrain makes it possible to test the two components as they interact. Comparability then exists on the system level. This is where the ›


*Testing on the test bench goes hand in hand with the development of an electric powertrain system of any type—from the concept to series production.*

## TEST BENCH SET-UP




*Simulation of relevant CAN nodes from the vehicle on the test bench*

performance limits of the later drive are tested.

Electric motors are not equipped with torque measurement technology in the vehicle. Thus the power electronics cannot directly regulate the torque. Generally speaking, the power electronics provide a current with which torque is generated. Through this correlation, a conversion from target torque into a target current and thus from torque control into current control is carried out. During the application, the electric motor is driven to various operating points. The parameters for the application of the characteristics and control maps are derived from the measurement values from the power electronics and the test bench. Of particular importance are the values from the torque sensor, which only exists on the test bench, so that a current/torque correlation can be established.

Beyond determining the machine parameters, additional development tasks are also a part of an application. The inverters, for instance, are generally outfitted with functions that protect the system against damage. This includes, for example, observing the current limits of the high-voltage (HV) battery and monitoring the temperature of the electric motor. For these functions to be applied, various specifications in the restbus simulation of the system environment must be changed in the meantime. These then provoke a reaction of the respective protective functions. Taking the example of current limits, the parameters would be set such that exceeding the battery current and thus damaging the battery are prevented.

Electric motors with permanent magnets are often used in the vehicle. Here it is important to bear in mind the temperature dependence of the magnets as the magnetic flux density of the magnets, changes with the temperature. The flux density is directly related to the generated torque, which is why torque would drop with a rising temperature. Development engineers refer to this as flux compensation. It compensates for the temperature dependence of the torque. For the compensation to be applied, an electric motor with special measuring technology (rotor telemetry) is required. Equipping such a machine with the appropriate technology is associated with dedicated machine design and carries additional financial costs. In this case planning security must be ensured through design freezes.

This applies in particular to the construction of the electric motor. All changes to the electromagnetic system—either to the materials or in terms of the connection of the cooling jacket after application of the temperature dependences—can adversely impact the torque precision, which in turn necessitates adjusting and updating the application across the various models.

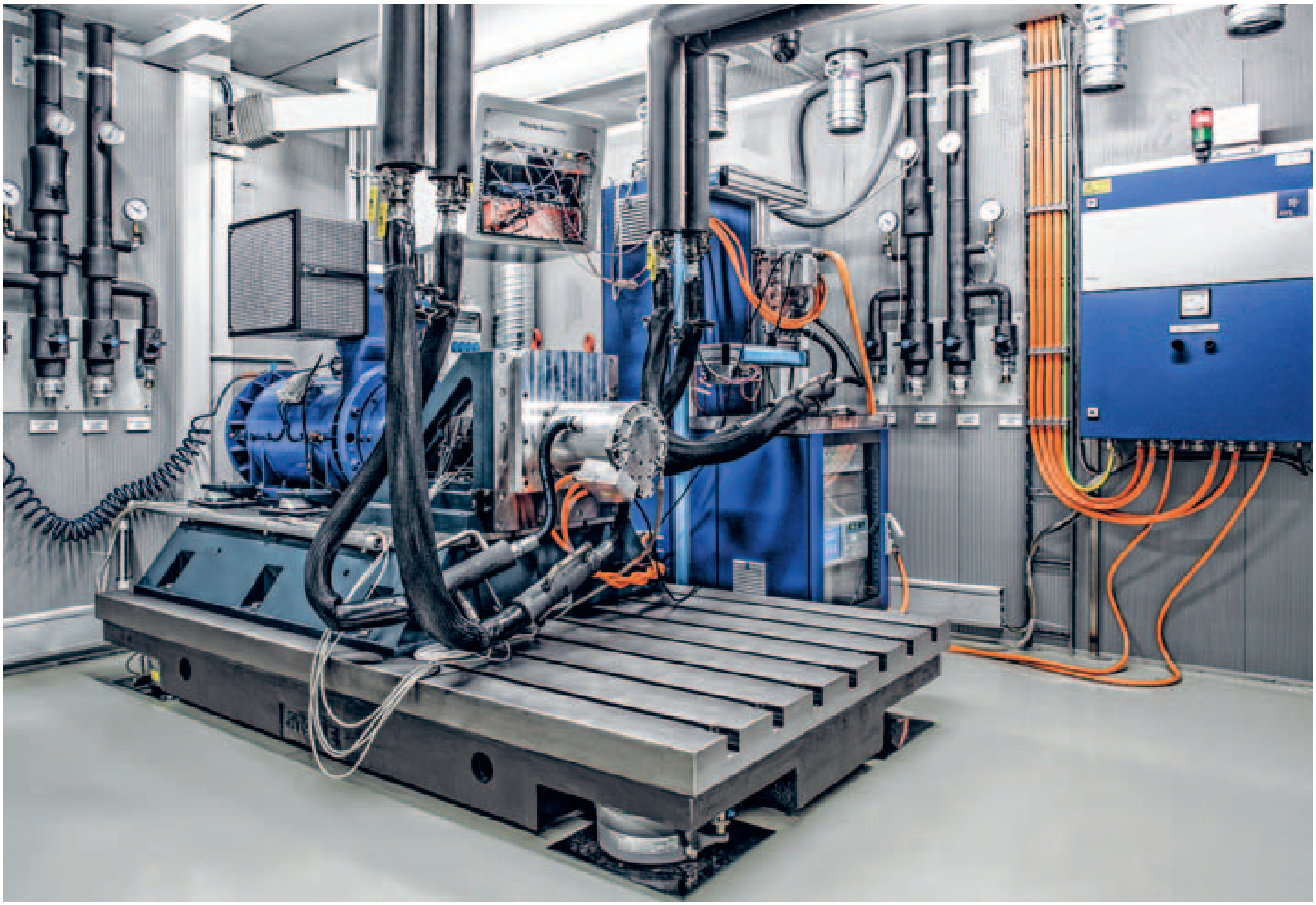
## Testing

The testing process distinguishes between the following four requirement categories:

- Performance
- Durability
- Abuse
- Reference measurement

In performance testing the focus is on the electric motor's performance data. Durability testing tests the long-term robustness of the electric motor. Special test cycles compress the thermal and mechanical load spectra for the lifetime of the motor into a period of a few weeks. Abuse testing checks potential malfunctions and faulty reactions. The reference measurement is used to determine variation in the performance data. Multiple motors of the same type are measured in succession to document the range of variance.

To ensure that all requirements can be tested, Porsche Engineering relies on its own test catalog that has proven its mettle time and again. It includes more than 70 individual tests from series development that cover all as- ›



*When using the test bench, the electric motor can be operated either with a universal inverter or with the inverter that will later be used in the vehicle.*

## TECHNICAL DATA

| **DC supply** | |
|---|---|
| Rated power | 250 kW |
| Max. high voltage | 800 V |
| Max. DC current | 600 A |

| **Load machine** | |
|---|---|
| Machine type | ASM |
| Rated power | 250 kW |
| Max. torque | 600 Nm |
| Max. engine speed | 15,000 rpm |

| **Coolant** | |
|---|---|
| $T_{min}$ | −40 °C |
| $T_{max}$ | +140 °C |

| **Measuring technology** | |
|---|---|
| Power measuring device | WT1800 |
| Torque measuring flange | HBM T12 |
| Porsche measuring technology | SMT 5 |
| Control unit access | ES593 |

pects of development. One of the important standard tests is checking the efficiency control maps. These values are then later used by calculation engineers, among others, to estimate the range of the vehicle.

In contrast to a combustion engine, an electric motor has a very large overload capacity, which can be several times the nominal power rating. To examine this time-limited overload range, a variety of maximum characteristics are determined. The definition of "time-limited" has usually already been defined in the design.

Beyond determining the indicators and control maps on the test bench, customer-relevant test cycles are also important. They represent the later user behavior in the vehicle and are differentiated according to market and vehicle class. The components reflect the mechanical and thermal properties in the overall system when operated in a customer-relevant cycle. Of interest here are stable and reproducible acceleration and driving comfort values that can hold their own against the requirements expected of vehicles with conventional drive technology.

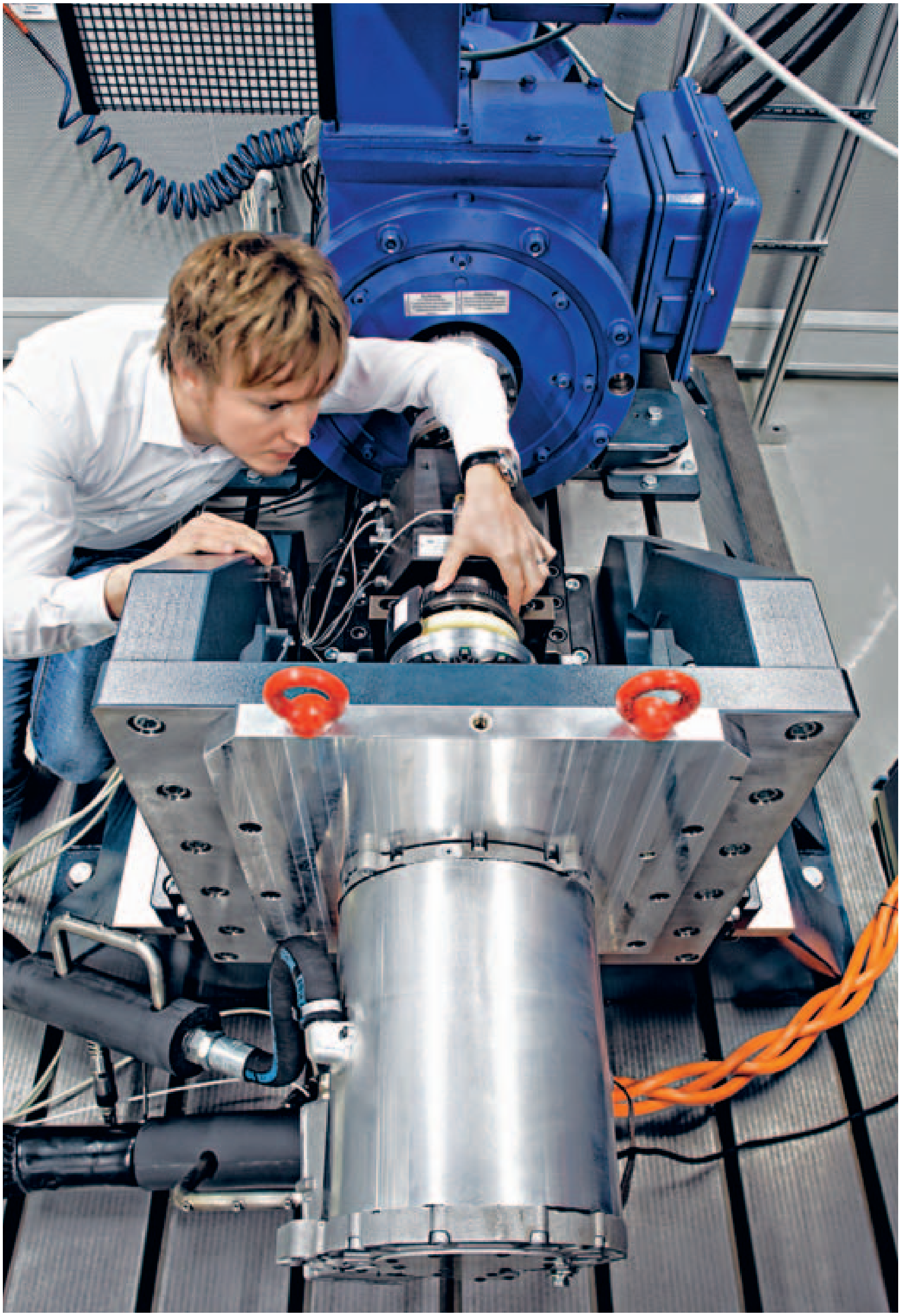
Beyond tests in the overall system or as individual components, the significance of a detailed view of subcomponents in the framework of testing is often underestimated. Porsche Engineering takes this into account in performance testing from the first concept onwards. Successfully integrating the drive in the vehicle requires attention to every last detail. One example would be the numerous environmental conditions in the automotive sector. For instance, developers are confronted with questions of material compatibility that normally do not occur in the standard environment of an electric motor. Early consideration of all factors makes it possible to recognize or avoid problems at an early stage.

In testing, the comparability and reproducibility of results are fundamental principles. The Porsche Engineering test bench has been validated against other internal and external test benches and the representation of the measurement results has been standardized. The new electric motor test bench is thus an ideal addition to the extensive Porsche testing landscape.

### Evaluation and analysis

During the testing stage, preliminary results are already being continuously analyzed by the test engineer. In case of errors or anomalies, timely special measurements are often required to identify the actual result. The earlier a problem is analyzed and the cause identified, the less significant the impact on the project. Errors discovered late in the project are considerably more cost-intensive than those identified at an early stage. The continuous checking of the results can minimize the probability of damage to the test object.

Every individual component is continually regarded from a complete vehicle perspective, with experts from the various fields of vehicle development ready to offer their input on an interdisciplinary basis at short notice. Problems often touch on multiple areas of expertise, and an overall view of the situation only



*Porsche Engineering always views each individual component in the context of the complete vehicle.*

emerges in consultations between experts from the different fields.

At the conclusion of testing, a report including a detailed interpretation of the results is created. The interpretation leads to a list of measures that the developers can use to refine their components and thus close the circle between design and testing. ■