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Saving battery costs by optimizing the inverter's control strategy for an efficient powertrain

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Executive Summary
The inverter test system is the right equipment to optimize the inverter's control strategy. As the inverter influences the other components in the powertrain, an optimized control strategy leads to an increased total efficiency. Saving battery costs or extending the driving range is only one of many advantages resulting from a well-optimized inverter operating strategy.
Moreover, it is always a question of the overall drivetrain efficiency and the single components' interplay to offer a cost-optimized vehicle to the final customer.

Keywords: power electronics systems, electric vehicle, electric motor drive, drive & propulsion systems, electric machine

1 The inverter as key component

The inverter as the heart and brain of the electric powertrain plays a critical role in today's electric vehicles. It is an intelligent mini-computer and controls various functions regarding comfort and safety while determining the efficiency and operating range of the drive unit. Therefore, every vehicle contains at least one inverter. Together with battery and e-motor, they form the basis for the final driving experience.

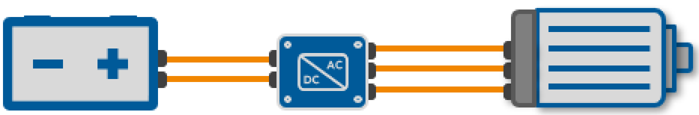

Fig. 01: Main components of an electric powertrain (© AVL SET)

A precise inverter test system with e-motor emulation technology allows new powerful optimization methods which would not be possible in a mechanical environment. The basis of such an inverter test system is the E-Motor Emulator (EME) with its power hardware-in-the-loop (PHiL) integration. It offers all testing possibilities in signal and power level efficiently, accurately, and fast without the need of mechanical e-motor testbeds.

The AVL Inverter TS™ consists basically of an e-motor emulation and a battery emulator – so there is no need to have the real e-motor and the real battery available. Also, residual bus, cooling, etc. will be emulated and only the inverter as Unit Under Test (UUT) is real.

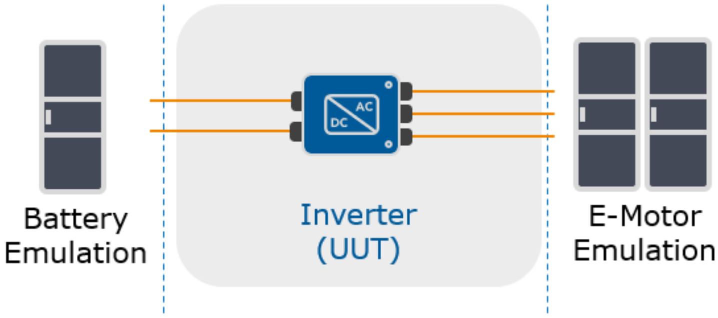

Fig. 02: Schematics of an inverter test system (© AVL SET)

1.1 But how to save battery costs when the real battery is not available?

The optimization of a complete electric powertrain is one of the main challenges for OEMs. The optimization of only one component can be a multiplicator for the overall efficiency and the influence of a single component must be validated with the total powertrain efficiency. For example, there might be a worse efficiency of the e-motor due to optimization of the inverter efficiency – then the main question is the total efficiency which should be higher than before.

As the battery is still the most expensive part in the powertrain, the optimization of the battery itself is mandatory.
The range of an ICE vehicle can be extended via a larger tank. Similarly, the battery capacity of an electrified vehicle would have to be increased to enable a greater driving. Vehicle manufacturers must find the balance between driving range and battery costs – which means the optimization of the battery and the complete powertrain efficiency. It is important to know that every component in the powertrain loses energy – mostly in the form of heat. If the efficiency of the powertrain is improved, it is possible to keep the driving range constant with a smaller battery. This can be realized by increasing efficiency through optimized control methods of the inverter. Reduced losses lead to a higher efficiency which leads to battery cost savings or a larger driving range.

Fig. 03: AVL Inverter TS™ (© AVL SET)

A wide variety of tests can be performed within an EME-based ideal inverter test system. Controller models as well as the hardware of the traction inverter can be validated and optimized. Via automation systems, early prototypes can be run through complex test scenarios under real and safe environmental conditions. The tests regarding functionality and safety can be performed with special testbed equipment for external failure generations such as for signal connections or short-circuits due to phase faults.

In addition, compared to the inverter validation in a real-world prototype vehicle, the setup and testing time can be reduced significantly.

The Inverter TS enables the testing of hardware and software integration as well as dedicated inverter software testing.

The efficiency of an inverter has a big influence on the total efficiency of the electric powertrain. The main factors are a variable switching frequency and low current ripples. The advantage of high switching frequencies are high dynamics and low current ripples which lead to low mechanical losses of the e-motor. On the negative side, there are higher electrical losses of the inverter itself. For low switching frequencies it is the other way around. Therefore, the total efficiency is always a question of the best ratio between low current ripple and high switching frequency. A state-of-the-art inverter control strategy includes a variable switching frequency concept.

1.2 Are there additional possibilities to optimize the inverter and powertrain efficiency to an optimum?

Yes, there are several more possibilities which can influence the total efficiency:

- Usage of 800 V technology and Silicon-Carbide (SiC) semiconductors.
- Usage of different inverter control strategies
- Usage of a block mode for sinusoidal current and pulse width modulation (PWM).
- Usage of precise rotor position within Permanent Magnet Synchronous Machines (PMSM).

2 Conclusion

The Inverter TS can easily be used for optimization of the inverter´s control strategy to optimize the inverter and powertrain efficiency to save battery costs. This can be realized with fast and easy e-motor and battery parametrization. The dedicated e-motor models can be modified to adapt the e-motor characteristics. The same can be done on the battery side. In addition, the inverter parametrization can be modified and the same inverter hardware with new software parametrization can be tested in a reproducible environment.

The test run for an efficiency map of the inverter can be set up in a short time and the execution just takes a few minutes. This is why it is easy and fast to repeat the test case several times for the iterative definition of the ideal inverter control strategy.

Presenter Biography

Michael Seeger, Key Account Manager and Sales Engineer at AVL SET GmbH
With company since 2021

Michael is part of the sales team and as Key Account Manager responsible for the whole Volkswagen Group worldwide. Creating reliable networks with his customers, providing customers with high-end solutions for projects in R&D departments at customers site and strong communication with his partners are his passion. Prior to joining AVL SET, he worked for other companies of the testing industry for the electrification of the automotive Industry.