TEST SYSTEMS

# High-end drive technology
## Engine Torque Pulse Simulation



Highly dynamic drive application featuring Engine Torque Pulse Simulation (ETPS) for driveline and transmission test rigs.

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01 Example: Conventional transmission test rigs with combustion engine can be upgraded to feature electric drive units along with combustion engine simulation.

Energy efficiency and driving comfort are increasingly demanded in the automotive industry. As such, the industry keeps investing in new drive concepts using innovative driveline technologies. These include dual-clutch gear systems that are dependent on the functional interaction and comprehensive data exchange with the control units of other driveline components and especially, the combustion engine control units in motor vehicles.

Aside from applying modern EDP-based design and simulation tools, the process of designing new driveline and transmission concepts inevitably involves performing test runs. The problem is that performing test runs with current vehicles is only possible to a limited extent.

Practical and economic factors, coupled with reproducibility requirements, therefore lead engineers to perform the vast majority of test runs and measurement cycles on test rigs. Most transmission test rigs for dynamic testing are designed in such a way that the original combustion engines from motor vehicles (series or prototypes) provide the input for the transmission test units.

Instead of the original wheels of motor vehicle, inverter controlled electrical load units are applied. These load units are used for the simulation of vehicle mass and road loads to generate dynamic driving profiles.

Given the developing technology in vehicles, their transmissions and driveline today, the pressure for innovation within the industry remains at an all-time high. Transmission development processes and their respective testing on test rigs have to be up and running when the respective combustion engine is still under development.

**These are just a few of the arguments supporting the full electrification of driveline and transmission test rigs, including the substitution of the real combustion engines by low-inertia electric drives featuring simulated combustion engines.**

Together these measures eliminate the effort of complex infrastructure and government safety regulations surrounding the use of combustion engines. Moreover, an emergency exchange between the energy for the power train and load units is created within the inverter system. The overall effect is to save considerable amounts of primary energy.

**Combustion engine simulation (ETPS)**
Another benefit of this method is the vastly improved flexibility of such test rigs. For example, it allows the simulation of different engines (diesel/gasoline) with different cylinders and other characteristics through the use of corresponding parameters.
In any combustion engine, the generated torque is largely effected by torque pulses (harmonic content) due to the ignition of the cylinders, the number of cylinders in the engine and other parameters. One of the main requirements for the simulation is to reproduce those typical torque pulses, which can achieve up to 300-400 Hz and more, as realistically as possible.

**The objective of ABB was to create a flexible engine simulation model with user-friendly parameter interface.**
The idea was to offer comprehensive, easy-to-handle parameter set-up options for engine modeling to meet highly complex requirements.

Given the frequent lack of all relevant engine parameters being available to engineers during the development phase, the challenge was to provide a diversity of options for simplified parameterization, thus allowing engineers to depend on a minimal range of parameter sets for maximum simulation accuracy.

In cooperation with the Institute of Automatic Control and Mechatronics (IAT) of Darmstadt University of

Technology in Germany, ABB has developed such a combustion engine simulation model with flexible parameter settings as required.
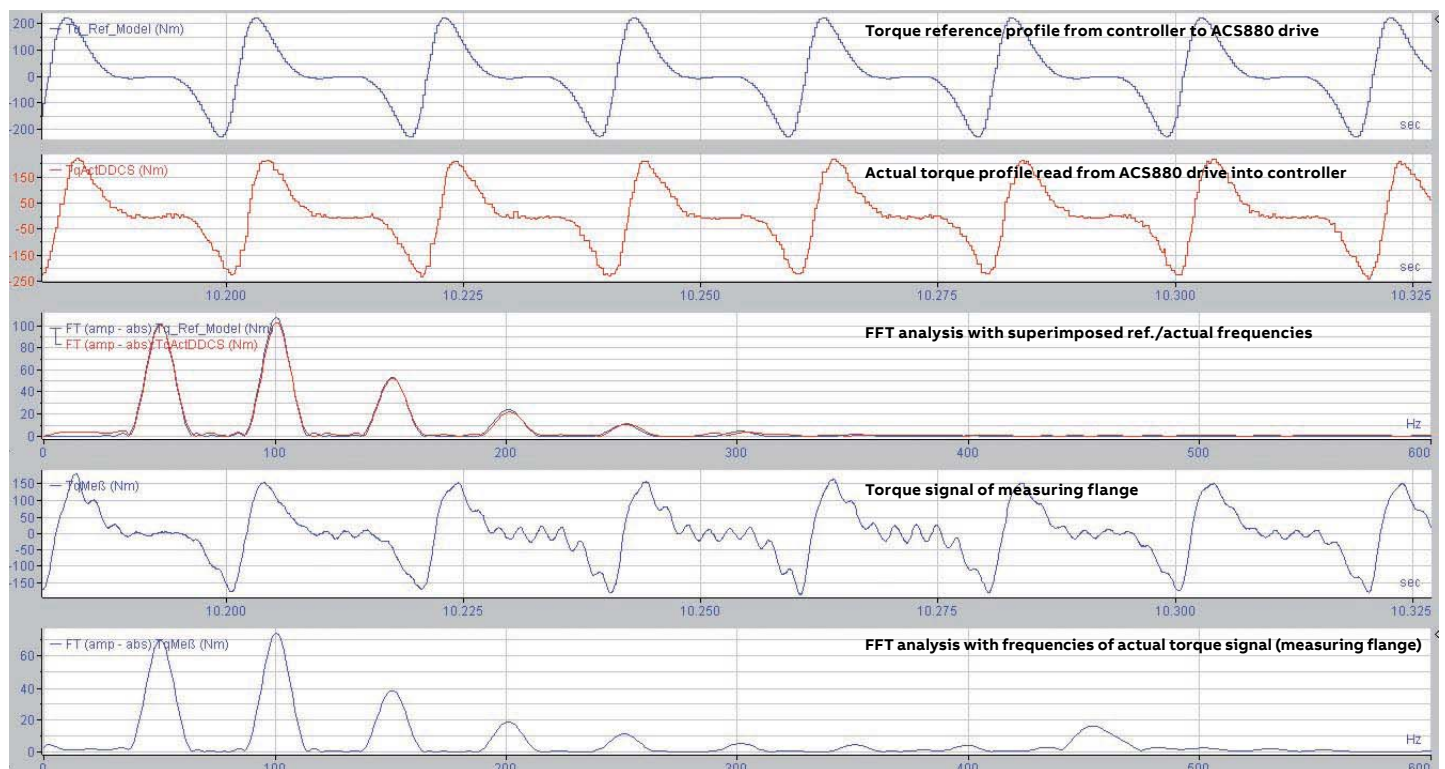
The simulation of the combustion engine, including its mechanical and combustion-related properties (number of cylinders, volume, compression, ignition, amongst others) is performed by means of a highly dynamic electrical drive system, based on a high-speed inverter-fed machine designed for maximum power density and an extremely low moment of inertia. The challenge involving the inverter was to generate the aforementioned high-frequency components as part of the pre-calculated amplitudes of the air gap torque in the electrical drive.

**Excellent simulation results**
The torque characteristic produced on the test rig with this concept is highly similar not only to those of far more complex engine models, but also to the validation data of real combustion engines. Take, for example, the following chart (picture 01) with ref./actual graphs and FFT analyses from a 4-cyl. diesel engine at 1,500 rpm.

The up-to-date ABB inverter generation ACS880 was applied to achieve such high dynamic demands. It features the latest, advanced version of ABB's Direct Torque Control method (DTC), faster signal processing as well as higher switching and output frequencies.

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01 Simulation results for 4-cyl. diesel engine timeline: 25 ms/div.

Processing of all the algorithms for combustion engine simulation is performed on the advanced ABB controller AC 800PEC, one of the most powerful modular controllers for high-speed applications. It can handle extreme real-time requirements such as sampling frequencies of 4 kHz and above. On the mechanical side, the shaft connection to the test unit has to be designed and optimized to transmit the frequency spectrum of generated torque, so that it is available at the interface to the test unit in the pre-calculated amplitude.
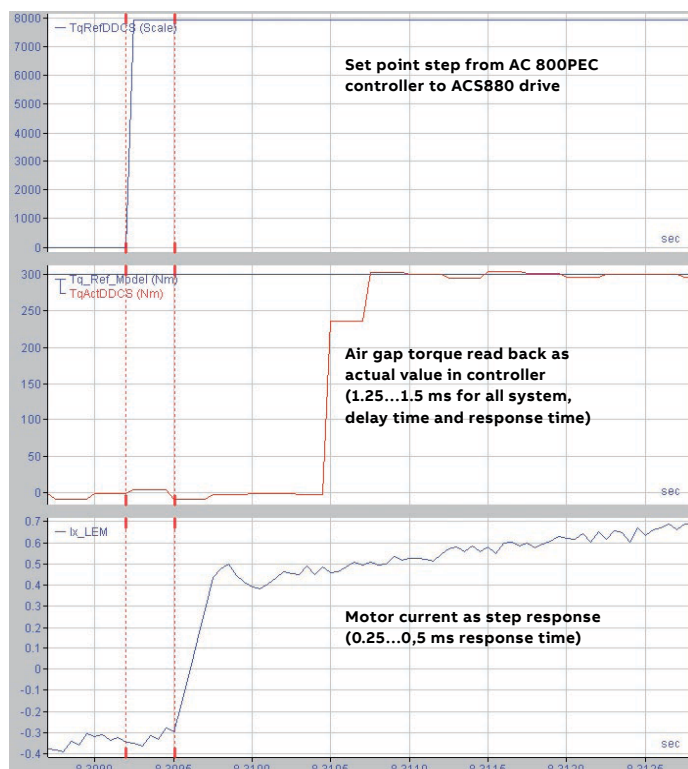
### The model basically includes the following features:

- Calculation of average torque based on engine speed and throttle position
- Superposition of zero-mean torque pulsation (harmonic content)
- Simulation of engine mass inertia
- The transfer of reference values and control signals from the AC 800PEC controller to the frequency converter is performed via high-speed DDCS bus (optical) link

### Highly dynamic drive system
As shown in the following chart (picture 02) based on a 0-300 Nm set point step, torque response time < 0.5 ms reflects DTC performance and its ideal suitability for ETPS applications.

### Saving energy and cutting costs
Compared to the conventional transmission test rigs using real combustion engines, the ETPS test rig offers our customers numerous advantages. With this new test rig, transmissions and drivelines can be tested without depending on the development progress of the corresponding engines. The new test rigs support them in optimizing the development process and furthermore, allow them to conduct development tests at an early stage under realistic environmental conditions with enhanced testing quality. The scalability of the electrical system of the new test rig, allows the customers to reduce the need for different real prototype combustion engines. Moreover, customers save additional costs in the supporting infrastructure for their test rigs, due to the consistently improved overall energy balance.

### ACS880 – New generation of frequency converters
The ACS880 is the first frequency converter that is based on ABB's new drive architecture. The base version alone already meets the vast majority of technical requirements, besides numerous factory options allow extensions. The new generation is significantly smaller than its predecessor. ACS880 features an easy-to-use handling and intuitive operation with a large high-resolution display.
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**Further info: www.abb.de/drives**

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02 Set point step and step response at 1,000 rpm
Timeline: 0.5 ms/div.

03 ACS880 with DTC control for most complex demands



Set point step from AC 800PEC controller to ACS880 drive

Air gap torque read back as actual value in controller (1.25…1.5 ms for all system, delay time and response time)

Motor current as step response (0.25…0,5 ms response time)

02



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