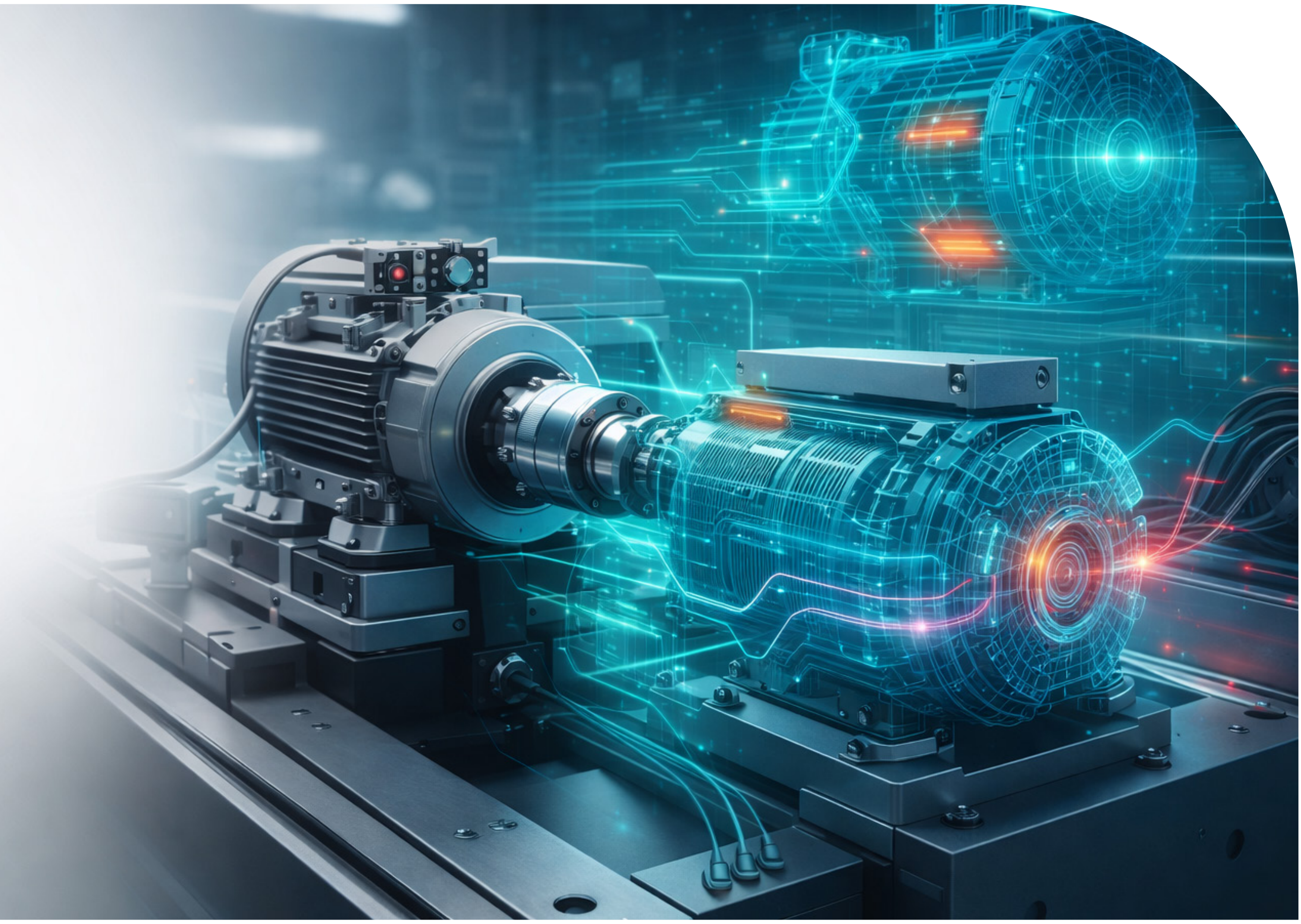

WHITE PAPER

Smart Testing: Accelerating Electric Motor Development with Integrated Simulation and Test

Introduction

Electric motor development is under increasing pressure. Electrification programs demand higher efficiency, lower losses, shorter development cycles, and fewer physical prototypes - often all at once. At the same time, motor behavior is becoming harder to predict due to tighter thermal margins, higher inverter switching frequencies, and complex control strategies.

Traditional development processes - where simulation, controls development, and physical testing are handled in isolation are no longer sufficient. In practice, this separation often leads to conflicting results, late-stage surprises, and reduced confidence in virtual validation. Engineering teams need workflows that connect real test data with simulation models, enabling faster decisions and higher confidence earlier in the design process.

HBK, together with VI-grade and MoBeLIV, a specialist provider of multiphysics electric motor models designed to be tuned with test data addresses this challenge through a Smart Testing approach that unifies multiphysics simulation and physical validation into a continuous, closed-loop workflow.

Why Traditional Motor Development Struggles

Despite advances in simulation tools, many organizations still face recurring issues:

- **Disconnected tools and teams**: Electromagnetic, thermal, control, and test activities often rely on separate tools, assumptions, and post-processing methods.
- **Limited correlation between simulation and test**: Models are often created early and validated late, leading to poor agreement with measured behavior.
- **Reduced prototype availability**: Cost and time pressures limit physical builds, increasing dependence on simulation -sometimes beyond its validated range.
- **Difficult-to-measure parameters**: Key quantities such as magnet temperature, flux, and detailed loss components often remain estimated rather than directly measured.
- **Slow iteration cycles**: Linear build–test–correct workflows delay insight and decision-making.
- **Electric motors are inherently multiphysical systems**. When these physical domains are analyzed separately, important interactions can remain hidden until late in development—when design flexibility is already limited.

Smart Testing: Closing the Loop Between Simulation and Test

Smart Testing replaces linear workflows with a continuous development loop. Instead of treating simulation and testing as separate activities, models and measurements inform each other at every stage.

At the core of this approach is a simple principle:

Use simulation to reduce unnecessary testing and use targeted testing to improve simulation fidelity.

This requires models that are fast, reusable, and closely aligned with real test data rather than assumptions alone.

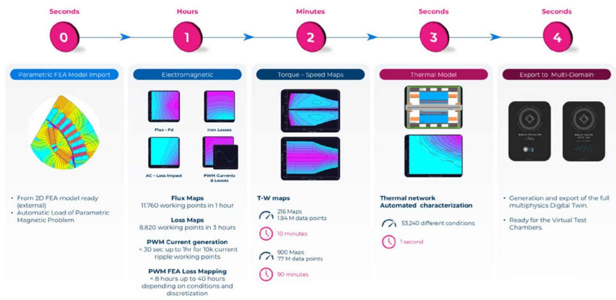

Figure 1: The MoBeLIV digital twin development process showing fast development time with multiphysics tools

Multiphysics Digital Twins for Motor Development

MoBeLIV enables this workflow through high-fidelity, multiphysics motor models that combine:

- Electromagnetic behavior
- Thermal networks
- Inverter and control effects, including PWM

Unlike traditional offline models, these digital twins are designed to:

- Fast enough for design-space exploration
- Tunable using measured test data
- Executable in real time for HIL and simulator environments

Built on MATLAB/Simulink foundations, the same model can be reused across concept design, laboratory validation, and real-time testing—eliminating redundant model creation.

Once validated, models can be deployed as protected, reusable components (often referred to as digital off-the-shelf motor models) for broader use across teams and programs.

Test & Tune – Turning Measurement into Trusted Models

A critical element of Smart Testing is the ability to systematically compare simulation results with physical eDrive test data and tune models accordingly.

Instead of post-processing test results in isolation, measured data is aligned with simulation outputs using standardized workflows. Differences between expected and measured behavior are identified, and models are refined using test data rather than manual rework or individual assumptions.

This test-and-tune approach improves correlation across simulation, SIL, HIL, and physical test environments -increasing trust in simulation results while reducing dependence on individual expertise.

Extracting More Value from Test Data with Virtual Sensors

Many of the parameters engineers care most about are either hard or impossible to measure directly:

- Magnet temperature
- Magnetic flux
- Loss segregation (PM, iron, AC copper losses)
- PWM ripple effects

By combining physical measurement from HBK eDrive test systems with tuned multiphysics models, Smart Testing enables virtual sensors- model-based calculations that run alongside measured data.

These virtual sensors allow engineers to:

- Gain insight without adding physical sensors
- Analyze difficult internal parameters offline or in real time
- Reuse the same validated computations across programs and teams

In many cases, virtual sensors become the primary source of insight for parameters that previously relied on estimation -bringing consistency and confidence to results across the organization.

From the Test Bench to Real-Time and HIL

Because tuned motor models are real-time capable, validated digital motors can be executed directly in:

- Hardware-in-the-Loop (HIL)
- Power HIL (PHIL)
- Real-time test systems using HBK computing platforms

Rather than starting with a digital-twin objective, Smart Testing allows teams to progress naturally - from offline simulation to test-tuned models, to real-time execution when the value is clear.

Once models are reliable, executing them in real time alongside physical measurements enables advanced insight during testing, reduces post-processing effort, and lays the groundwork for practical digital twin applications.

Placing the Motor in Its System Context

Electric motors never operate in isolation. Load cases, drive cycles, and control behavior significantly influence performance.

Integration with VI-grade simulation platforms allows tuned motor models to be evaluated in a broader system context, including:

- Vehicle dynamics and load variation
- Control interactions
- NVH and efficiency trade-offs

This system-level perspective helps teams identify risks earlier—before design changes become expensive or constrained by hardware.

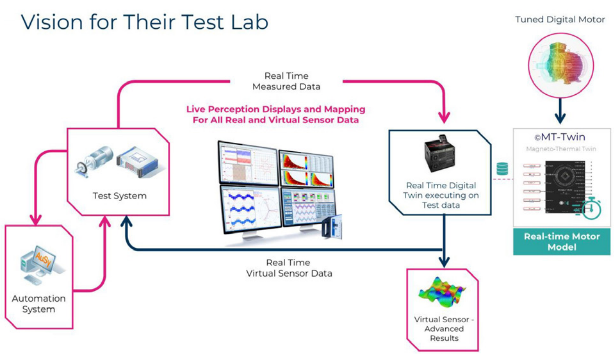

Figure 2: A test stand showing digital twins executing motor models at the edge for virtual sensors or reduced post processing time

Enabling Standardization Across Teams and Programs

In many organizations, different teams analyze the same motor using different tools, equations, and assumptions- leading to inconsistent results and reduced confidence.

By unifying simulation, test data, and post-processing within a single workflow, Smart Testing enables consistent computation methods across departments. Engineers see the same results whether they are working in simulation, in the lab, or in real-time environments - reducing rework, debate, and dependency on key individuals.

Conclusion

As electric motor systems become more complex and software-driven, development processes must evolve. Treating simulation and testing as independent activities is no longer sustainable.

By unifying multiphysics simulation, real-world test data, and system-level context, Smart Testing enables a more agile and confident approach to motor development. HBK, VI-grade, and MoBeLIV together provide a scalable framework that helps engineering organizations move faster, reduce risk, and extract greater value from both simulation and test data.

HBK – Hottinger Brüel & Kjær
www.hbkworld.com
info@hbkworld.com