

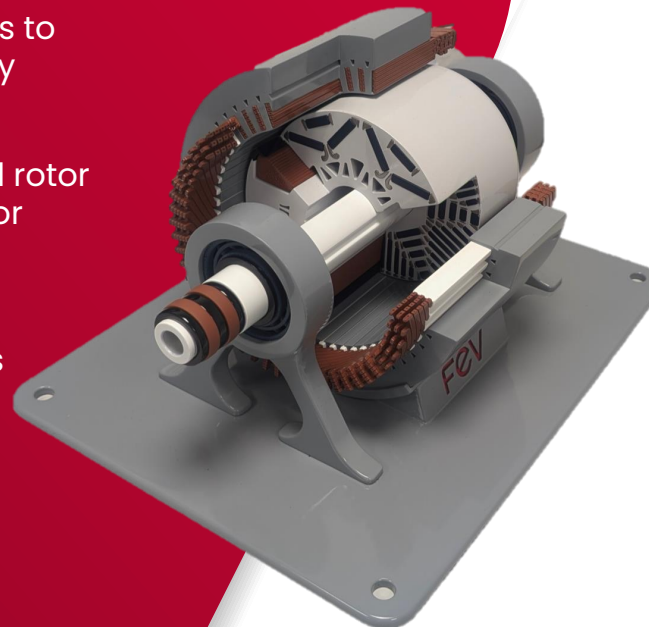
FEV Signature Solutions

Electric machine solutions

Accelerating your development: From concept to road-ready

FEV offers

- ▶ Scalable electric machine concepts supporting cost-optimized production across multiple power classes
- ▶ Innovative electric machine architectures supporting interchangeable rotor technologies to address cost, sustainability, or material-supply challenges
- ▶ Advanced cooling concepts (direct stator and rotor cooling, hollow-conductor hairpin cooling, rotor spray cooling, magnet cooling) enhancing performance at high power
- ▶ Accurate NVH and loss-prediction capabilities resulting in quieter, more efficient machines
- ▶ Fast test-bench evaluation for validation, benchmarking and optimization



Why FEV?

- ▶ 45+ years of automotive engineering excellence, trusted by global OEMs and Tier-X suppliers to deliver innovative, production-ready solutions
- ▶ 10+ years of proven electric machine development across multiple machine topologies and industries
- ▶ End-to-end engineering services, covering concept studies, electromagnetic, thermal and mechanical pre-design, development, simulation optimization, validation and integration
- ▶ Transparent and customizable solutions, enabling you to extend, integrate, and scale your own development
- ▶ Prototyping capabilities and partnerships for series production

Selected reference projects

ELECTRIC MACHINE SOLUTIONS

- Permanent magnet excited synchronous machine (PMSM)
- Electrically excited synchronous machine (EESM)
- Induction machine (IM)
- Axial flux machine (AFM)

German OEM **Testing**

Induction machines up to 12,000rpm / 5500Nm with various testing applications

European OEM **Simulation**

Concept study and electromagnetic pre-design to find suitable designs for a given application

US Tier-2 **Simulation and Testing**

Tear down of a BMW i4 EDU and creation of a validated electromagnetic simulation model of the EESM

German OEM **Testing**

Permanent magnet synchronous machines up to 20,000rpm / 600 Nm

German OEM **Development**

Externally excited synchronous machine concept development without rare-earth materials

European Tier-1 **Integration and Testing**

Electric machine system integration and benchmarking of YASA axial flux machines

German Tier-1 **Development and Testing**

Scalable electric machine and inverter product family from scratch to SOP for non-road mobile applications

German Tier-1 **Simulation**

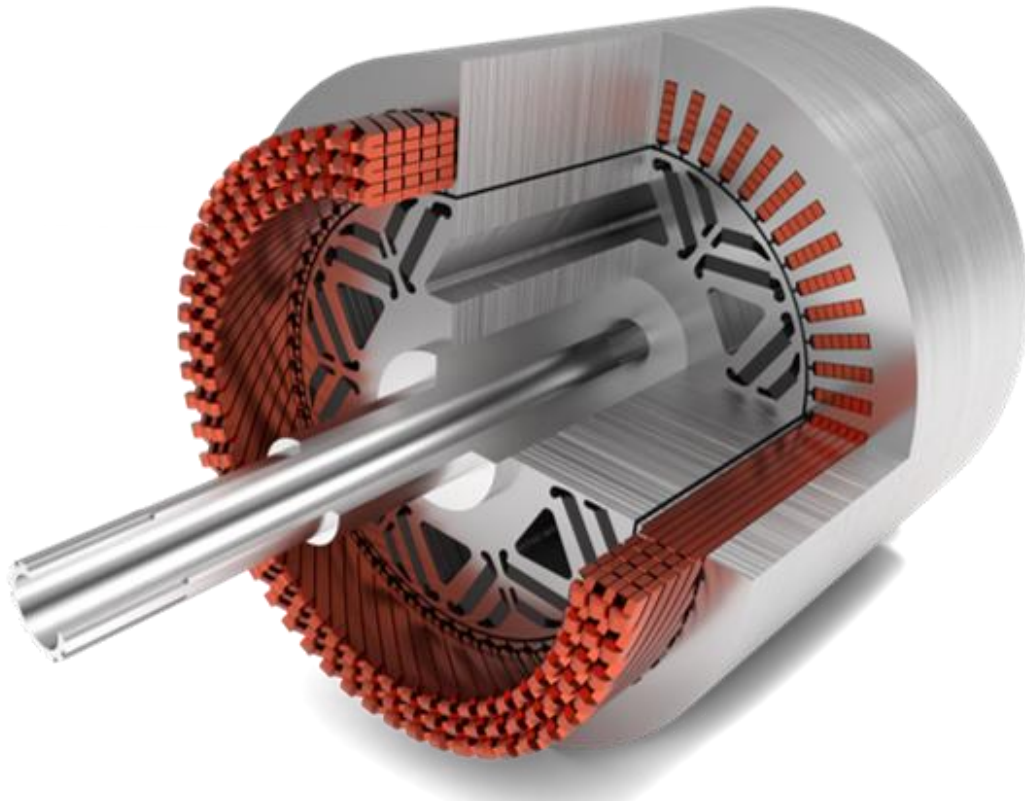
Calculation of radial and tangential electromagnetic force densities for NVH investigations

German OEM **Simulation**

Reduction of eddy current losses in PMSM balancing discs due to induced eddy currents for different variants

FEV's electric machine 360° approach

ELECTRIC MACHINE SOLUTIONS AS PART OF FEV'S ELECTRIC POWERTRAIN ENGINEERING



Concept Study and Pre-Design

Identify the best suitable machine concept early, leveraging FEV's benchmarking database and expertise, to reduce risk and ensure the best balance of cost, efficiency, and materials

Electromagnetic Design

High-fidelity electromagnetic simulations (2D/3D, multiphysics, NVH forces, loss analysis) deliver higher power density, improved acoustics and efficiency, and fewer redesign loops

Mechanical and Thermal Design

Advanced thermal and structural simulations and optimization enables cooler operation, longer lifetime, and higher sustained performance, especially at high speeds

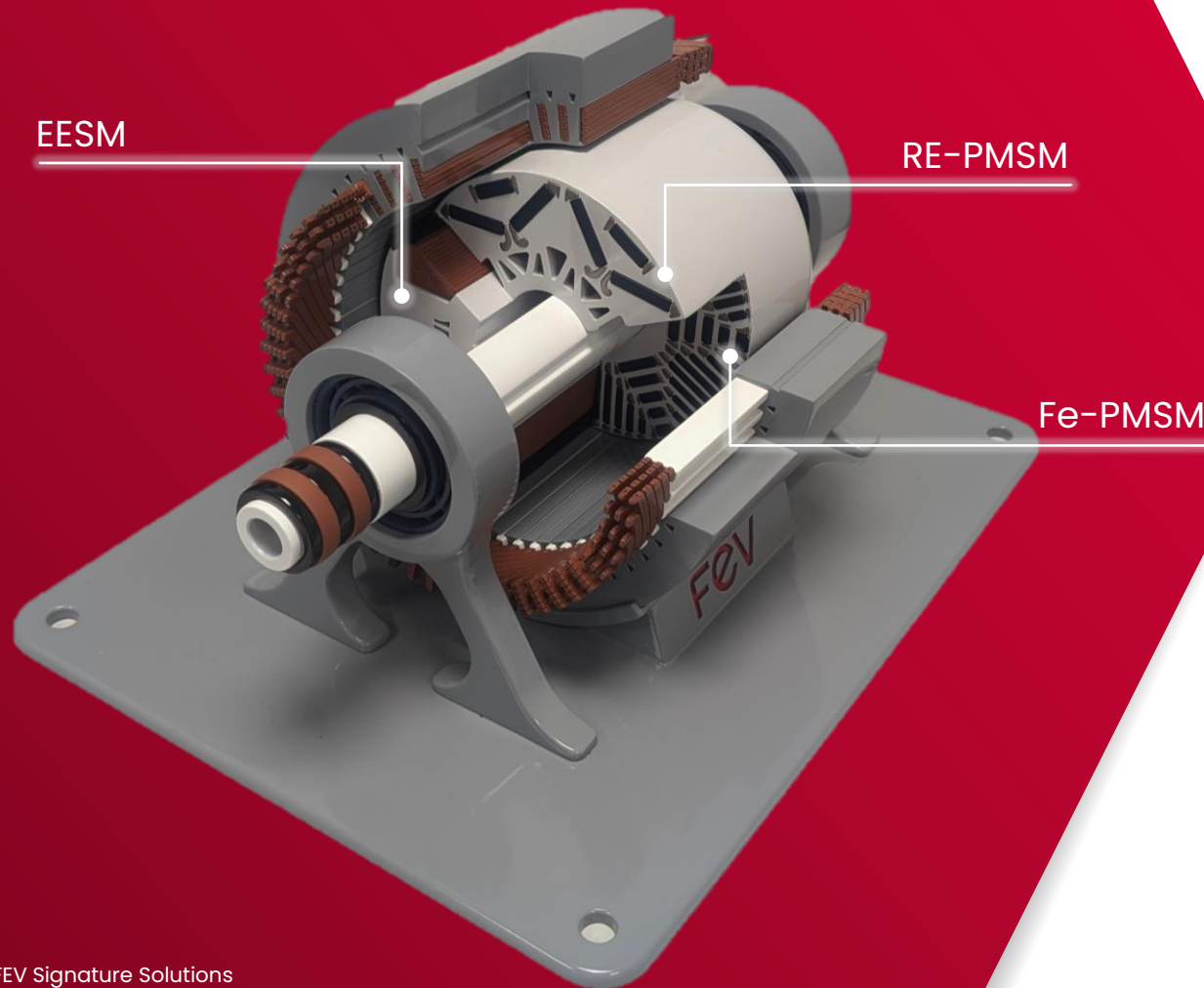
Validation and Testing

Access to FEV's global test centers accelerates functional validation, durability assessment, and environmental compliance, shortening your time-to-market

Integration

Seamless system and vehicle integration, including power electronics adaptation, ensures the electric machine performs optimally within the complete electric powertrain

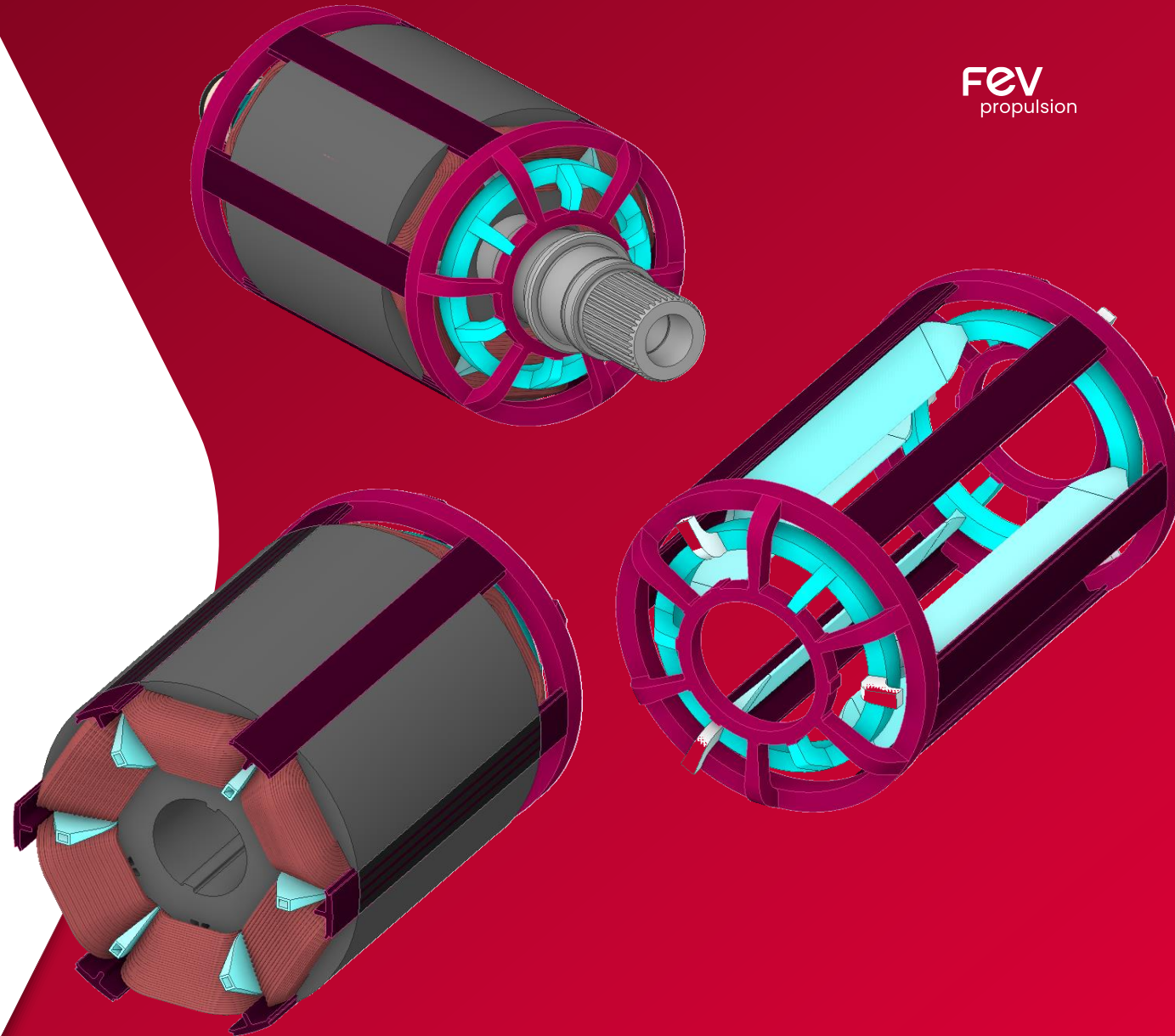
Our modular rotor technology for flexibility, performance and cost control



- **Modular rotor concepts** allow switching between rare-earth (RE), ferrite (Fe), externally excited, or induction technologies to address cost, performance, or supply-chain constraints.
- **Advanced rotor cooling solutions** improve thermal stability, enabling higher continuous power and efficiency.
- **High-speed rotor retention designs** enhance mechanical robustness for demanding applications.
- **Rare-earth-free magnet alternatives** reduce material cost and dependency risks.
- **Optimized hairpin and winding strategies** support performance, NVH, and manufacturability targets.
- **Integrated telemetry and inductive power transfer** for externally excited synchronous machines (EESMs) enable precise rotor control and monitoring.
- **Common stator/housing concept** simplifies manufacturing and reduces development effort across multiple machine variants, addressing different vehicle platforms.

FEV's rotor cooling and structural innovation for higher performance and reliability

- **Integrated mechanical-plus-cooling rotor cage** distributes coolant efficiently, while providing robust structural support for high-speed operation
- **Significantly improved rotor cooling** for externally excited synchronous machines (EESMs) with high copper losses, enabling higher continuous power and superior thermal stability
- **Optimized temperature control** of permanent magnets in permanent magnet synchronous machines (PMSMs) protects magnet health and ensures reliable peak performance
- **Enhanced high-speed rotor strength** reduces mechanical stress from centrifugal forces, supporting demanding operating points
- **Higher efficiency and durability** through improved cooling uniformity and reduced thermal hotspots, translating into longer component life and stable operation



Beyond the motor: Our complete EDU and powertrain engineering support

- We support you across the **entire electric drive system**, from electric machine to fully integrated EDU and powertrain.
- **System-level engineering from one partner**, covering electric machine & transmission, in-house power electronics (inverter, DC/DC, OBC), and inverter software.
- **Full life-cycle support** from concept and specification to SOP, series operation, and on-site production support.
- Efficient development through **integrated engineering services** addressing manufacturability, reliability, and robustness.
- **Proven validation and testing expertise**, combined with know-how in series-proven and next-generation electric drive technologies.

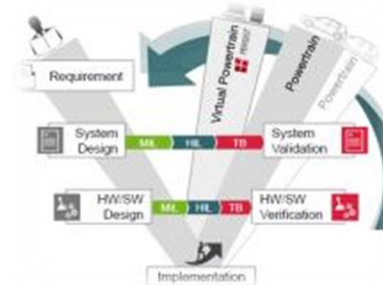
1 Electric machine development



2 Power electronics development



3 Software and controls



4 DV and performance testing



Get in touch with us for further information



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