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Next gen EDU with innovative Electric Motor and Inverter technologies development

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This short paper presents the concept and technological approach of the next-generation high-voltage Electric Drive Unit (EDU) developed within the EU-funded HiVEP project. The system integrates a three-level SiC inverter, a rare-earth-free IPMSM with Active Winding Reconfiguration (AWR), an integrated charger concept (I-CHARGER), a high-C-rate battery system, holistic thermal management, and an Explainable AI (xAI)-based supervisory control. Operating around 1000 V, the architecture aims to enable ultra-fast charging, improve efficiency, reduce cost, and minimize dependency on critical materials, contributing to the wider adoption of mass-market battery electric vehicles (BEVs).

The widespread deployment of BEVs remains limited by long charging times, system-level efficiency constraints, high manufacturing cost, and dependence on critical raw materials such as rare-earth magnets. These challenges become more pronounced under high-load and fast-charging conditions, where electrical losses and thermal limitations reduce overall performance and user acceptance. To address these issues, the HiVEP project adopts a system-level approach that increases the powertrain voltage beyond the conventional 800 V level, reducing current, minimizing conductor losses, and creating a broader operating window for high efficiency.

Increasing the system voltage to approximately 1000 V is a central architectural decision that defines the operational environment for all major subsystems. At this voltage level, current can be reduced significantly without the insulation complexity associated with 1200-V-class systems. This provides a favorable foundation for power electronics, electric machine, battery, and charging functions to operate closer to their optimal efficiency regions. The project targets include achieving 20–80 % charging in under 10 minutes, improving system-level energy consumption by at least 25 %, and enabling roughly 21 % additional driving range without increasing battery mass.

A core component of the architecture is the three-level SiC inverter. The selected T-type Neutral Point Clamped topology reduces device count and switching effort compared with alternative multilevel designs, supporting compact implementation and reduced verification workload. The use of SiC MOSFETs improves inverter efficiency, lowers switching and conduction losses, reduces thermal load on the cooling system, and enables a more compact overall design. These characteristics contribute directly to the system-level efficiency improvements and downsizing benefits targeted by the project.

In addition, the EDU uses a rare-earth-free IPMSM equipped with Active Winding Reconfiguration. Instead of relying on rare-earth magnets, the motor employs ferrite-based permanent magnets and switching elements that allow the stator winding configuration to change dynamically during operation. This capability enables the motor to adapt to differing voltage utilization and efficiency requirements in low- and high-speed regions. By adjusting copper losses and voltage demand through AWR, the motor maintains competitive efficiency across its operating range despite the use of non-rare-earth materials. Simulation and Hardware-in-the-Loop evaluations confirm smooth transitions between winding configurations and compatibility with automotive NVH and drivability requirements.

The architecture also incorporates I-CHARGER that reuses existing inverter and motor components to perform DC charging. Through this concept, a low-voltage DC source can charge a ~1000 V battery by operating the EDU as a boost converter. The resulting functional integration reduces hardware mass, volume, and cost while providing a basis for future bidirectional functions such as Vehicle-to-Grid (V2G) or Vehicle-to-Home (V2H). In combination with a high-C-rate battery and coordinated thermal management, the EDU supports the high electrical and thermal demands of ultra-fast charging.

By combining these technologies, the HiVEP project proposes a coherent high-voltage platform that enhances efficiency, reduces cost, and lowers the dependence on critical raw materials. The integrated design improves charging time, driving range, and energy use without increasing battery size. Environmentally, reduced rare-earth usage and higher system efficiency contribute to lower life-cycle emissions. Economically, material reduction and functional integration improve competitiveness for high-volume BEV production.

HiVEP introduces an integrated high-voltage powertrain architecture combining power conversion, motor control, battery operation, thermal management, and system control. This unified approach effectively addresses fast charging, efficiency, and cost targets. Upcoming hardware-in-the-loop (HIL) and vehicle testing will confirm feasibility, positioning the architecture as a foundational BEV technology supporting future sustainable mobility.

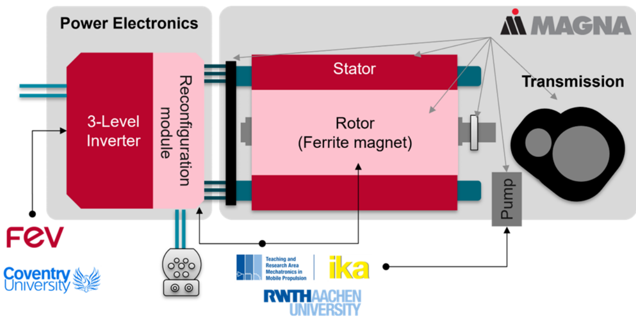

Fig. 1 EDU Architecture