

# Engine Electrification for Leaner, Greener Vehicles

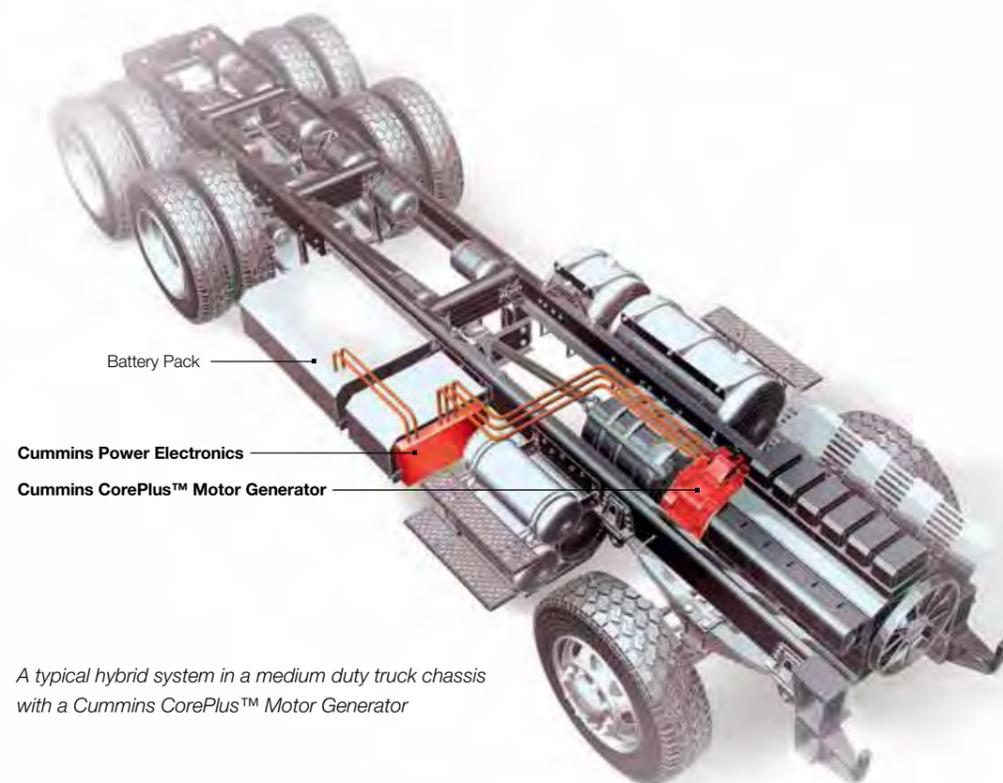
**Cummins Generator Technologies' all-new patent-pending electric Motor Generator with CorePlus™ technology offers a high-torque solution to commercial vehicle manufacturers seeking the electrification of their drive-trains, all in an impressively compact package.**

The 'double-whammy' of spiralling fuel costs and ever tightening laws on exhaust emissions is forcing commercial vehicle operators to look for leaner, greener alternatives to conventional diesel engine topologies, particularly in urban areas where air quality is a growing concern. Given their proven ability to save fuel and reduce emissions and CO<sub>2</sub> diesel, electric commercial vehicles offer many advantages over their diesel-only equivalents, the most obvious being that an additional electric motor provides zero emission 'green' motive power during the all important starting-off phase, where most fuel is burned by a standard vehicle.

Incorporating an electrical motor generator into the drive-train of existing commercial vehicles is not without its problems. Naturally the motor has to provide sufficient power to accelerate a laden hybrid commercial vehicle away from rest, giving it a performance that's traffic

compatible with other road users. But it must also be small enough to avoid any chassis packaging problems for the vehicle manufacturer, and light enough so the truck's payload isn't compromised either. No easy task! The good news is that the latest Cummins radial-flux motor generator, with its peak power of 90kW and 660Nm torque, measuring 200mm in length and with a weight of just 108kg, comfortably meets all those hybrid commercial vehicle challenges.

Cummins Generator Technologies' hybrid drive investigations stretch back to 2000 when it originally set up an R&D team to examine new market opportunities for permanent magnet generators and power electronics converters. Although the group's focus was initially towards power-generation applications, in particular to help reduce the fuel consumption of diesel generating-sets, especially on mobile generators where similar challenges (notably size and weight) exist, it also found a market for its products in the military sector. Having developed specially packaged permanent magnet motor and power conditioning systems for special military projects, the natural next step was to develop a permanent magnet machine and power electronics converter specifically for the hybrid commercial vehicle market.



A typical hybrid system in a medium duty truck chassis with a Cummins CorePlus™ Motor Generator

Cummins new CorePlus™ Motor Generator can be used in either series or parallel hybrid drive-train configurations, or a combination of both, with its 'universal' hollow rotor design allowing it to fit application dependent drive-shafts. Weight has also been saved in the machine rotor casting which only has to handle the torque produced by the electric motor rather than the torque from the diesel engine.

The motor is liquid (water-glycol) cooled by a water channel integrated within its aluminium housing; the water-cooling manifold, containing two threaded o-ports, allow the customer to fit a range of inlet and outlet connector pipes to the manifold. Hoses from the cooling system can then be connected to these pipes. By designing the cooling manifold as a separate component, customers have greater flexibility in the positioning of the motor within the truck's drive-train.

Building a motor that's light-yet-powerful, with a high torque, and which takes up as little space as possible brings with it thermal and mechanical design-issues. To ensure the smallest external dimensions, the new Cummins Motor Generator features a permanent magnet topology with a high number of poles and concentrated non-overlapping stator winding. These maximise the available space in 'short' machines by reducing the length of the end turns, in proportion to the stator core pack length. The stator slots are 'open', enabling the use of externally-wound coils, featuring plastic bobbins that are then inserted into the stator. This technique allows a high degree of manufacturing automation and a very good slot-fill factor.

During the concept stage our engineers considered a number of different permanent magnet rotor configurations including: Surface magnet; inset magnet; and embedded

magnet (with either a flat or 'V'-shape). Ultimately, the embedded magnet layout offered the best solution thanks to its mechanical retention and environmental protection of the magnets, good field-weakening capability and low short-circuit current.

Likewise, having looked at flat and flux-focusing V-shape magnets, a flat magnet installation was chosen as the best solution thanks to a lower magnet mass per unit (lower flux leakage than a V-shape), lower rotor inertia-end constraints for the rotor's internal diameter and a simpler manufacturing process with a lower number of magnets.

To optimise the complex electromagnetic, thermal and mechanical factors Cummins' engineers applied a number of different computer-based design and modelling tools during the motor's development, examining a number of technical and design options within a relatively-short period of time. In particular, computer-based systems allowed a detailed 3-D analysis of the segmented rotor in order to provide a full insight into optimal magnet temperatures, as well as the motor's overall thermal performance. Cummins Generator Technologies also devoted much time to fully-integrating the power electronics controller into the overall hybrid-system, ensuring a highly efficient and full torque-speed operating range for the motor.

The result of our endeavours is a lightweight and dimensionally-compact motor generator that can be fitted to any manufacturer's drive-shaft, with a very high peak-torque rating and good efficiency over the entire torque-speed range, ensuring a highly-flexible hybrid drive-train capable of delivering impressive fuel savings. That's a definite 'win-win' for both commercial vehicle makers and operators alike.

## Cummins Motor Generator Quick Spec-Check

- Peak torque - 660Nm
- Peak power - 90kW @ 1,300rpm
- Continuous power - 35kW @ 1,300rpm
- Motor efficiency - > 95%
- Overall length - 200mm
- Weight - 108kg
- Cooling - water-glycol



A typical Cummins CorePlus™ Motor Generator