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A Bosch Company

The global equipment 700-volt segment, serving agriculture, construction, mining and other industries, has seen a rapid expansion of electrified machines that can efficiently, productively satisfy the operational requirements that these heavy-duty machines face

Electrification of Mobile Machines: New Challenges and Opportunities

Equipment manufacturers in every major global market are launching full-electric and diesel-electric vehicles in order to respond to increasing market demands, reduce carbon footprints and stay competitive with state-of-the-art technologies.

As a result, original equipment manufacturers (OEMs), drivetrain providers, and other technology suppliers are working to advance their portfolios and system designs. The common goal: improve how battery-powered and diesel-electric systems move off-highway machines and power their implements.

The push for electrification does not mean the eventual replacement of hydraulics with electric motors will occur; rather, the industry will work toward electrifying off-highway platforms in the most efficient ways possible, to make maximum use of the advantages provided by hydraulic and electric technology.

ELECTRIC-DRIVEN MACHINES MOVE TO THE FOREFRONT

Heavy-duty construction, agricultural and working machines that typically use diesel engines to power their drivetrains and hydraulics are now rapidly being electrified; some construction equipment suppliers now offer a complete line of heavy-duty machines that are all battery electric. This class of equipment is often referred to as the high-voltage machine class.

Multiple industry drivers are powering this electrification movement:

- Total cost of ownership: As electrification expands, battery-electric and diesel-electric drivetrains are more competitive. Combined with the expanding availability of electric charging stations and the impact of fuel cost inflation, electrified heavy-duty machines are becoming more feasible.
- Serviceability: Electric motors and drivetrains are inherently simpler machines compared to combustion engine systems. Their reliability and ability to operate with longer duty cycles with less maintenance and repair make them much more productive and cost-effective to use, especially since they can deliver the same power and performance in demanding work environments like construction sites and agricultural fields.
- Controllability: An electric motor offers instantaneous torque control, which may result in fine-tuned control of the drivetrain with a superior level of productivity, compared to combustion engine and hydraulic drivetrains. Electric system control algorithms give operators the ability to manage battery life through proper power distribution in a simpler manner. In addition, controllability of hydraulic driving equipment implements can also be fine-tuned with variable-speed electric motors driving the hydraulic pumps.
- Environmental/regulatory concerns: In many major markets, evolving emissions and air quality regulations continue to affect construction OEMs. In certain urban environments, noise and emissions regulations have led to OEMs launching all-electric, small skid loaders, wheel loaders and other equipment capable of working in restricted sites.

MANAGING THE DEMAND FOR POWER

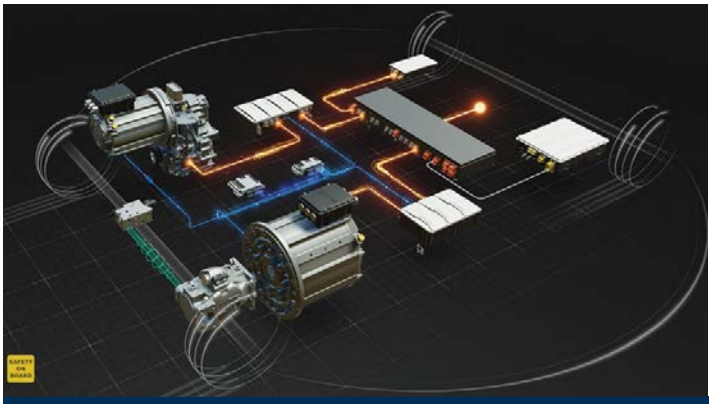
Battery storage and power management technology, and the efficiency with which electric drivetrains use that power, continues to make rapid progress. In the 700-volt segment, OEMs have swiftly moved from prototypes to successful machine designs, building on a new generation of batteries, motors, inverters, gear units and advanced software platforms for traction and implement control. Nevertheless, for construction, agricultural and other off-highway applications, creating and consistently delivering the power needed to move the machine and/or its load lies at the heart of mobile machine engineering. Applications and operating environments matter.

For example, a combine harvester working in a rural location moves constantly over acres of distance, with some implements being hydraulically powered and others with less demanding requirements (such as steering control) using electromechanical devices. For a fully electric combine, the availability of high-kilowatt (kW) recharging stations or other power sources in remote locations to recharge this kind of vehicle could remain limited. One interim solution already being implemented by some OEMs is to have replaceable battery packs for machines operating under these conditions — it would be a standard service that would be established and managed remotely, enabling battery-electric machines to continue making inroads in these off-highway applications.

High-performance gearboxes, like the Bosch Rexroth eGFT, combine space-saving designs with high-power density and provide the optimal gearbox ratio for the extended electric motor speeds.

MODULAR APPROACH TO POWERING DRIVETRAINS

With current electric motor technology, most heavy-duty mobile machines can use electric motors for their drivetrains as a direct replacement. The greater challenge is how that electricity is generated and supplied to the electric drives. Multiple methods exist, and some are more unique than others — hydrogen fuel cells or combustion engines that run on natural gas and other fuels, for example.



Bosch Rexroth's eLION portfolio, comprising motors, inverters, cables, power distribution units, DC to DC converters and on-board chargers, offers mobile machine OEMs a powerful new platform to accelerate electrification.

The power source for the drivetrain and implements will continue to be driven by what the machine needs to do in its duty cycle, as well as its operating environment. So, a modular, application-driven approach will include:

- Conventional combustion engines: The standard diesel engine still delivers optimum performance in applications where the machines operate constantly, as in remote locations, and make heavy demands on travel and implements, such as mulching equipment.
- Diesel-electric: In this configuration, the drivetrain motors and hydraulics power is provided by a combination of a combustion engine and electrics drawing from batteries. This configuration is similar to hybrid passenger vehicle cars and trucks. For some construction vehicles, this can be a plug-in vehicle; the battery can be charged from a fixed utility line, so the diesel engine doesn't have to run to power the drivetrain or implements. Or, the engine can be operated in a load-leveling mode where the unused engine power is used to charge the batteries in the system.
- Full electric: These are battery-powered machines with the capacity to support extended periods of workload and are able to recharge between shifts or use replaceable batteries if a charging infrastructure is not available.

Major technology suppliers like Bosch Rexroth have launched new mobile equipment electrification platforms designed specifically to meet the demands of the 700-volt industry segment with motor-generators and inverters to support performance ranges from 8 to 200 kW. In addition, there have been advances in gearbox technology specifically designed to deliver maximum productivity and efficient use of power when combined with electric motors. These high-performance gearboxes combine space-saving designs with perfect matching of the gearbox ratio for electric applications.

ELECTRO-HYDRAULICS FOR POWERING IMPLEMENTS

To succeed, mobile machine electrification needs robust, reliable technology to ensure the machine's implements have the power they need to do their jobs. Electrification in off-highway applications must make optimum use of electric and hydraulic components. It takes a certain amount of power to enable the implements to handle the job — which calls for hydraulic pumps, valves and electronic controls that are both compact and powerful enough to fit into tight machine enclosures while providing the required performance.

As electric drives replace diesel engines to power the implement's hydraulic pumps, leading hydraulics providers are engineering a new generation of pumps and other hydraulics components. Until recently, hydraulic pumps have been designed around diesel engine speeds, noise levels and engine frequencies, among other characteristics. The next generation of hydraulic pumps are designed to couple with electric drives, operate optimally with the natural frequencies of electric motors and respond more efficiently to drives with a much greater range of speeds, rather than the low idle and high idle of a combustion engine.

ELECTRIFICATION AND SMART MOBILE ELECTRONICS

One of the most critical "enablers" of electrification of the 700-volt mobile machine segment is the major advances in electronic controls. Sophisticated advances in power management software created specifically for heavy-duty mobile machines are making it possible to stretch mobile machine duty cycles without compromising equipment performance or productivity. This efficient power management software is not limited to managing drivetrain power consumption; leading technology suppliers also have advanced implement controls that build on in-depth expertise optimizing hydraulics performance.

For example, electronic load sensing (eLS) is an established controls technology that adjusts the hydraulic pump displacement dynamically, based on flow requirements at different actuator load levels. The newest version of this kind of technology combines electric-powered hydraulic pumps with pre-compensated valve platforms, such as the RM mobile control valve, to more reliably ensure that the required hydraulic power is available and integrates advanced recuperation to maximize machine efficiency.

ADVANCING MOBILE MACHINE ELECTRIFICATION

The newest generation of 700-volt electric motors and inverters, along with a new generation of gearboxes, hydraulic components and controls, is rapidly advancing the pace and potential applications for diesel-electric and battery-electric heavy-duty mobile machines. It's also clear that hydraulics has a vital role in these machines, due to the reliability and power density that only hydraulics can supply. As construction, agricultural and off-highway OEMs expand their electric portfolios, there are advantages to working with technology suppliers with broad experience designing innovative, productive and proven solutions that utilize both kinds of technologies to advance mobile machine performance and value.

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USH00334/07.2022

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