Beside a wide range of automation products, Bosch Rexroth can help with DC testing systems by supplying scalable DC power solutions, be it power supply and management components, DC inverter power stacks, chokes, capacitors, cooling systems and necessary accessories, as well as design and commissioning support.

Overcoming Challenges and Boosting Productivity for EV Battery and e-Axle Testing

After more than a century of the world's automotive systems being powered and driven by gasoline and diesel internal combustion engines, the irreversible transition to electric vehicles (EVs) is underway.

All the major global automotive car and truck manufacturers are committed to transitioning the bulk of their vehicles to full electric transport by the mid-2030s. As a result, the performance and efficiency of the EV's battery pack and its electric motor powertrain (the e-axle) now makes them two of the most critical vehicle systems. An EV's battery pack is much more than just a power storage unit. It's a complex system composed of batteries in modules or sub-packs, combined with advanced wiring technology and sophisticated battery management systems (BMS). This enables the storage and fast movement of power in two directions: discharge to the powertrain and other EV systems, and in addition, efficient and repeated recharge, capturing energy from regenerative braking of the vehicle as well as fully recharging from charging stations.

CRITICAL NEED: TESTING AND VERIFICATION OF BATTERY & E-AXLE PERFORMANCE

As with conventionally powered models, electric vehicles are rated for their energy efficiency and operating range on a charge by the Environmental Protection Agency. This operating range is a critical performance metric used by vehicle manufacturers, industry experts and consumers to assess the value of an EV and compare different makes and models. Most critically, as more and more vehicle buyers seriously consider purchasing all-electric vehicles the certified operating range will become a vital number for buyers to assess who may harbor concerns from “running out of juice” mid-journey. For example, the Ford F150 Lightning, the first fully electric version of America’s most popular vehicle for more than 40 years, has over 190,000 reservations and counting.

EV manufacturers are therefore making major investments in high-performance testing platforms for their battery packs and e-axle systems. These testing systems leverage the latest digital tools, using advanced DC inverter power management technology to efficiently test and verify the charge and discharge cycles of their battery packs. Furthermore they simulate and verify the modular power conversion, energy regeneration and energy draw of their e-axles (electric drives and motors of the EV).

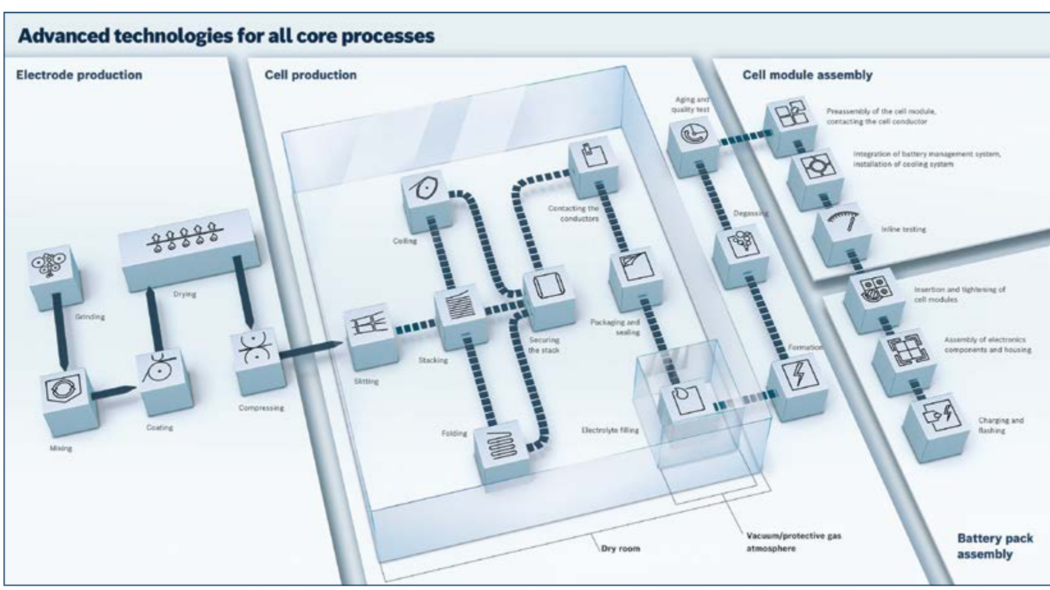
CHALLENGES FOR BATTERY PACK AND E-AXLE TESTING

EV battery packs are composed of multiple battery modules, which are themselves composed of multiple cells; the number of modules varies, from two to eight, although battery design continues to evolve. The battery packs also include state-of-the-art cooling technology and advanced BMS controllers, which compute, track, monitor and manage the available energy/charge in the pack. The BMS also controls the energy discharge (when the EV demands energy) and recharge (when power is fed back into the battery via regeneration and/or full charging).

End-of-line battery and e-axle testing systems must take into consideration the challenges associated with high-output mass production of vehicles using them — by one estimate, a plant producing 50 EVs an hour would have a new battery pack to test every 72 seconds. Battery packs and e-axles are complex devices, with size and weight dimensions that require careful handling to move efficiently through testing systems.

Bosch Rexroth’s IndraDrive ML scalable range of inverters enables effective solutions for battery pack and e-axle testing, with a scalable DC/DC drive design that provides the smallest footprint and weight to save valuable control cabinet space.

In response to these challenges, a new generation of battery and e-axle testing systems is being developed, built around a combination of advanced testing software modules and the



Electric vehicle battery fabrication is a complex multi-step process. The critical end-of-line step is charging and testing the battery pack through a full cycle of discharge/regenerative charging/full power charging steps to ensure each pack delivers its specified performance and has the specified state of charge.

latest generation of high-performance industrial inverter drives. These high-power inverters, such as the modular and scalable Bosch Rexroth IndraDrive ML, provide the safe, controlled and rapid delivery of DC power to the test stands, in order to supply/remove the correct amount of power to battery packs and e-axles according to the testing program's requirements.

The versatility of the Rexroth IndraDrive ML platform makes it easier for EV manufacturers to select one common inverter power stack for power supply, inverter and DC/DC converter to support both battery pack and e-axle testing systems.

The system topology for the battery charging and e-axle testing systems is similar, although not completely identical. The EV manufacturer creates the master testing program, which typically runs on an industrial PC and controls the specific charge and load cycles. These cycles are designed to match real world demand specifications, for driving, regeneration and charging, and to verify that the e-axle and battery performs as designed, by comparing command and actual data point, as well as EV equipment data.

The high-power inverter technology is crucial to this testing platform. It provides the modular power conversion, taking the plant's main AC power and converting to DC, then delivers power efficiently to DC/DC inverters on a common DC bus. DC/DC inverter set(s) are connected to the battery pack being tested, interfacing with the test computer and BMS to carry out the discharge, recharge and full charge cycles as dictated by the testing program.

The DC/DC inverter and the BMS provide the data real-time the testing system needs to evaluate whether the battery pack or e-axle is performing according to specifications: the BMS computes, tracks and monitors the available energy/charge and the EV's computer computes the available range, based on the vehicle's drives and electric motors. The testing system inverter power supply can report real-time voltage, current and power as each battery pack or e-axle is cycled through the testing sequences.

KEY INVERTER FEATURES FOR EV TESTING SYSTEMS

To support the rigorous, high-throughput testing demands for these systems, the scalable inverter technology plays a central role. They need to be efficient systems that can support very dynamic current ramps into the EV inverters and/or battery, charging and discharging power at the required voltage, and exercise tight control of the power flow.

The most crucial performance consideration for testing system inverters is their ability to support a broad range of DC output voltages and currents. One reason this is critical is that EV manufacturers have been increasing their battery packs' storage and output capacities. Older battery packs were often limited to approximately 420 volts (DC), and the charging systems were limited in power (typically 11 kW to 50 kW). These could take too long to charge from 20% to 80%.

EV manufacturers are moving to more powerful packs — in the 800 V to 900 V DC range — so it is important to select testing system inverters that can deliver broader output voltage ranges, from 20 V to 1150 V DC, and ever increasing DC output current demands, e.g. beyond 2000A. Equally important is the inverter control mode: How tightly can it control the required output by providing constant voltage, current and power according to the power cycling required in the testing.

For example, the Rexroth IndraDrive ML inverter provides very precise and accurate control, with less than 0.1 percent ripple (EV DC power systems have virtually no ripple). This is due to the high dynamics in its power stage and controller section and the closed loop measurement at the DC/DC converter output.

Given that numerous battery and e-axle test stands will most likely be needed to support high-volume automotive manufacturing, inverters that support reliable and clean DC power and efficient bus sharing are an important consideration. Inverter cooling is equally important, given that banks of inverters will need to support multiple test stands in a high-throughput end-of-line testing environment. Liquid-cooled inverters can support high power density and effective heat dissipation, helping make the testing equipment more energy-efficient and minimizing floor space demands. In addition, liquid cooling is also the cooling method used for batteries and e-axles.

One final consideration is safety: Inverters with industry-standard, well-designed safety disconnects and safe motion/ safe torque-off capabilities that are integral software elements of the inverter controller make it much easier to implement safety protocols to protect workers and testing equipment.

WORK WITH EXPERTS IN ELECTRIC DRIVE TECHNOLOGY

It is clear that battery pack and e-axle test stands will be critical production tools EV manufacturers will depend on to ensure that the vehicles they deliver to customers leave the plant with the set state of charge (SOC), discharge and full charge performance customers expect.

Today's leading suppliers of industrial electric drives and inverter technology have deep experience creating inverters engineered to meet demanding automation requirements. EV manufacturers and their production equipment suppliers can benefit from this expertise as they further evolve their testing capabilities. This can accelerate the creation of systems that can efficiently and accurately complete testing cycles and enable them to meet the rapidly rising demand for electric vehicles.

As EV manufacturers and their production equipment suppliers build their battery fabrication, e-axle production lines, and assembly plants, they are also building end-of-line test stands.

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USC00051/07.2021

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