



Automation Technology To Improve Battery Production Speed to Market

BATTERY TECHNOLOGY IS ESSENTIAL TO THE MODERN WORLD

Batteries are everywhere, in smartphones, tablets, laptops, wearables, VR sets, implantable devices, and all sorts of electric vehicles, from off-road construction and agricultural ones to watercraft, forklifts, tugs and even aircraft.

All these elements of our modern world, and many more, depend on electric batteries to operate efficiently, reliably and cost-effectively. The growth of widely distributed Internet of Things devices, video systems and sensors all depend on batteries to operate, while the continued scaling of solar and wind power is driving demand for new, more powerful and safe electric grid storage batteries to balance supply and demand.

As more and more opportunities for electrification emerge, battery performance and quality take center stage in the way the modern world operates. Along with the vastly expanded demand, this is driving unprecedented scale-up of battery manufacturing.

This increased productivity must be matched with the highest levels of product quality. If manufacturers ramp up too quickly, it can lead to manufacturing challenges in the areas of product quality and yield. Quality, safety and replicability are of utmost importance.

AUTOMATION SOLUTIONS FOR BATTERY MANUFACTURING

Battery manufacturers are seeking smart, adaptable automation solutions to help solve complex manufacturing process challenges and stay flexible as battery technology develops and demand surges.

Bosch Rexroth is ready to meet those challenges, combining deep battery manufacturing expertise with complete factory automation solutions, tailored to meet complex battery production requirements.

For battery manufacturing, our cross-technology portfolio includes:



Advanced controls and drives built around the revolutionary ctrlX AUTOMATION platform



Sophisticated and robust transport technology, such as the Flexible Transport System



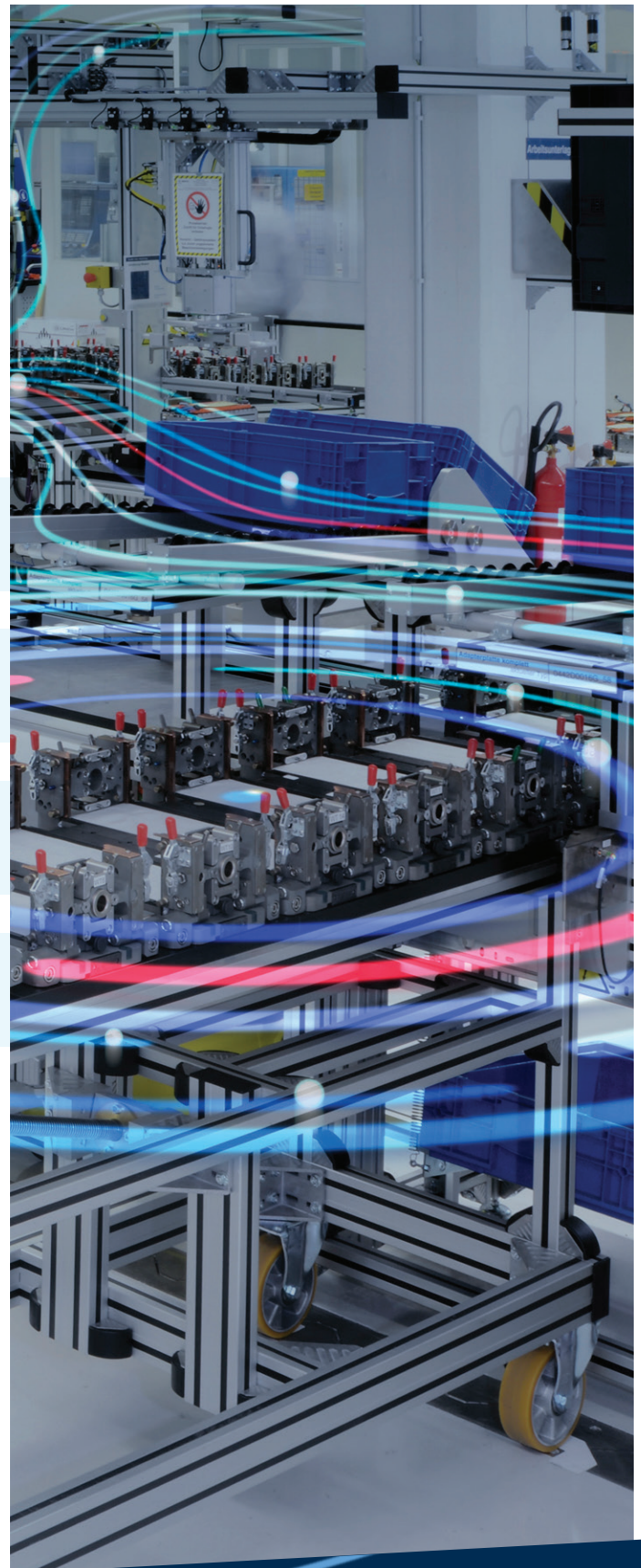
Smart MechatroniX plug-and-produce platforms for assembly and handling applications

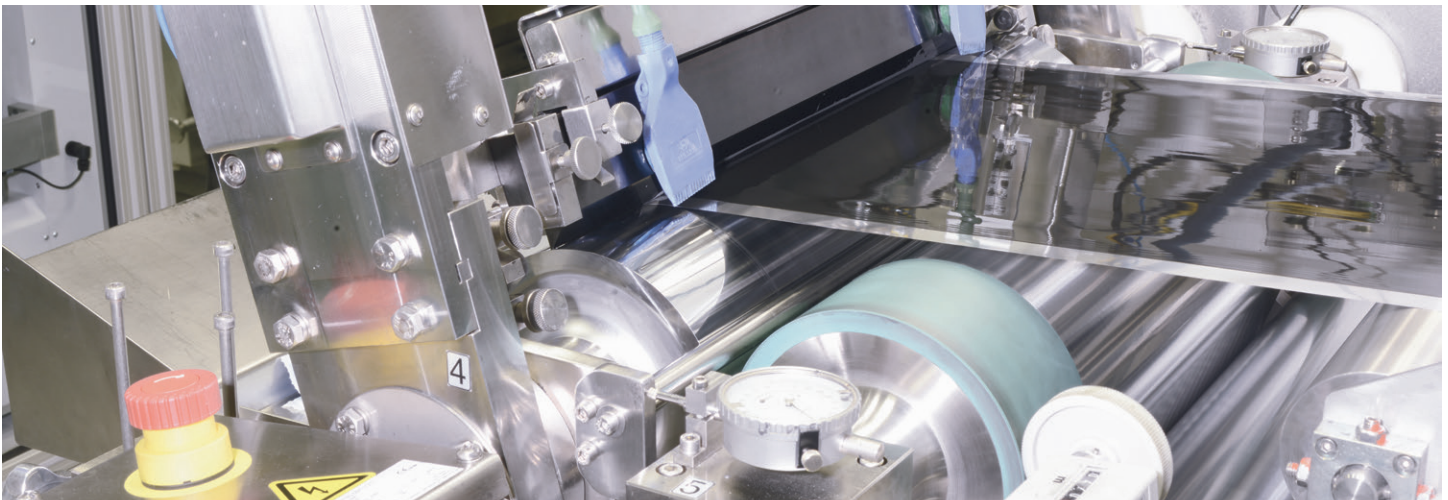


Battery testing systems

We combine this unique automation portfolio with deep expertise in solving manufacturing challenges and real-world battery production line engineering and implementation experience.

Our innovative, flexible and complete production solutions enable battery manufacturers to get to market faster through production systems that target key manufacturing steps for electrode production, cell production and battery module and pack assembly processes.





Electrode production utilizes high-speed coating processes requiring exceptional multi-axis synchronization and precise motion control.

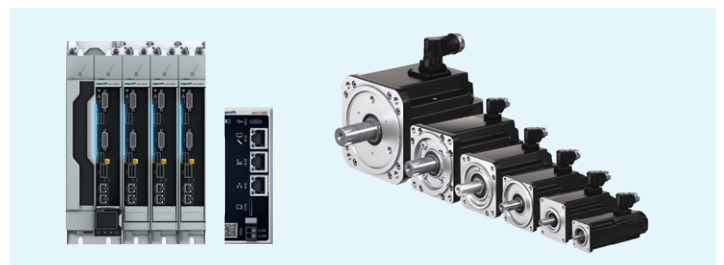
ELECTRODE PRODUCTION

One of the most critical challenges with electrode production is precise quality control as raw materials are taken through processing steps, from grinding and mixing to coating, drying and compressing.

To ensure these highly automated processes yield anodes and cathodes of the highest quality, maximizing control over the coating calendaring process is crucial. This requires exceptional high-speed multi-axis synchronization and highly accurate pressure and position control to eliminate variations in production.

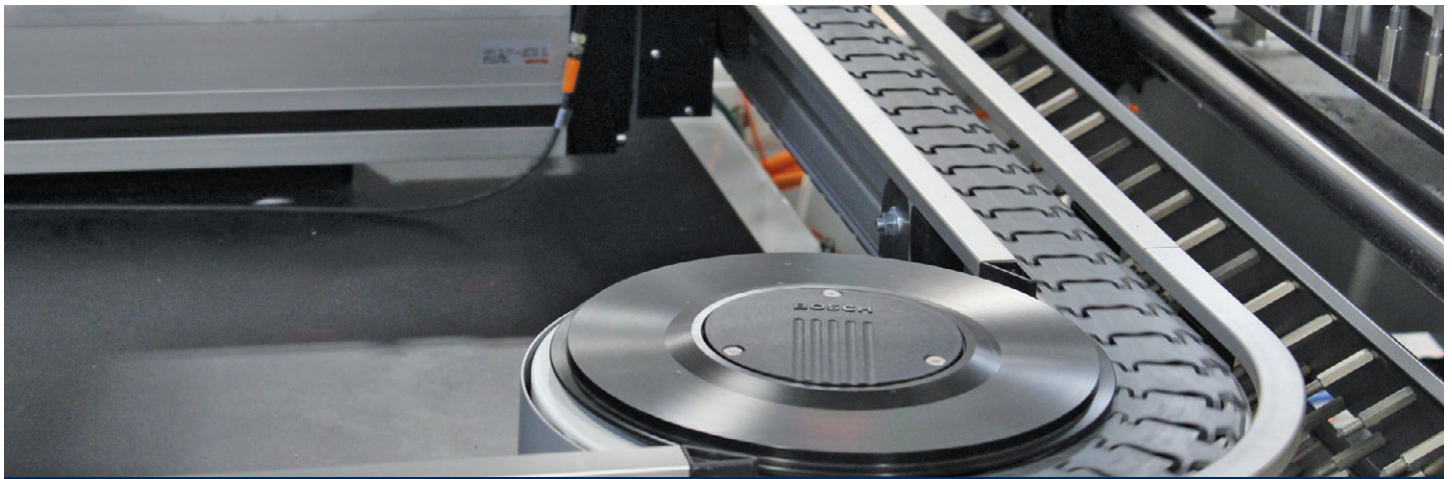
Bosch Rexroth has decades of experience advancing calendaring controls and drive platforms. Our ctrlX AUTOMATION platform provides exceptional, real-time synchronization and tension control across dozens of axes, maintaining high throughput and high registration of thin foils. The platform features a built-in library of motion control sequences for closed-loop sag and loop control for precise material feed, helping reduce web breakage and minimize waste.

The ctrlX CORE controller features high-performance Linux-based multicore technology and an open, app-based platform that lets users easily create, add or share automation functions – just like using smartphone apps. This makes it easier and faster to implement or change the specific machine functionality, as battery manufacturers evolve and refine their electrode production processes.



Advanced ctrlX CORE controller and Rexroth servomotors

Bosch Rexroth also provides advanced electromechanical technology for calendaring systems. The EMC-HP electromechanical cylinder is a compact, robust actuator specifically developed for heavy-duty applications like high-speed calendaring. It features a high-precision planetary screw drive that ensures exact positioning – with maximum control accuracy and dynamics.



Flexible high-speed transport systems are critical elements in battery cell production and must effectively balance throughput and accuracy to sustain quality.

CELL PRODUCTION

While each cell technology – cylindrical, pouch, prismatic and solid state – poses its own manufacturing challenges, all require high-speed transport systems to sustain targeted production levels.

This calls for smart balancing of throughput and accuracy. High-volume production lines are targeting electrode stacking rates down to 200 ms per layer. At the same time, as cells reach various assembly stations, positioning may need to be as tight as ± 200 micron endpoint accuracy.

Every battery production line is unique – which is why Bosch Rexroth's portfolio of transport systems gives manufacturers options that are readily adaptable to fit specific material transport needs.

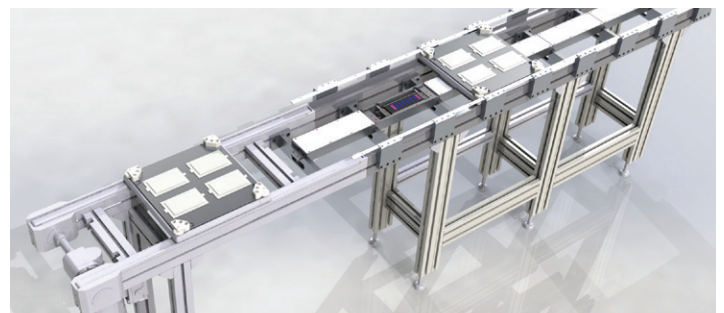
Rexroth's VarioFlow *plus* offers a powerful and versatile conveyor system highly suited for high-density automation and tight spatial constraints. It is a flexible, modular plastic chain conveyor able to move high-volume products horizontally, vertically and around obstacles. It can provide an efficient solution for delivering battery components, such as cylindrical cell cans and endcaps, as well as entire cells to the module assembly machines by offering speeds up to 100 meters per minute and low noise operation.

For more demanding applications, the Flexible Transport System (FTS) is a high-performance magnetically propelled transfer system for the highest-throughput processing machines. The FTS can handle loads from a few kilos up to 2,000 kg, all while offering speeds up to 5 meters per second and positioning repeatability of ± 20 μm .

It offers both individualized and synchronized material movement, as well as extreme positioning accuracy and high repeatability.

For heavier-duty battery production applications, the FTS supports:

- Product weight: 1-1000+ kilograms
- Pallet size: up to 1.5 meters x 2.8 meters
- Maximum acceleration: 40 meters/second²
- Pallet-to-pallet position accuracy: ± 0.02 millimeters



Linear motor-driven Flexible Transport System

Linear motor conveyors like ACTIVE Mover and FTS make it possible to use the conveyors as the x-axis in a wide range of automated assembly processes. Both systems can move the workpiece asynchronously under the process tool. Every carrier's movement – direction, speed, start and stop rates – is individually programmable. With this increased flexibility, system designers can leverage transport technology to help speed battery manufacturing productivity and throughput.

MODULE ASSEMBLY

Once cells have been produced, most battery manufacturing operations need to combine those cells into fully functioning battery packs. This requires multiple material movement and assembly process steps that often utilize a sophisticated mix of automated and targeted manual assembly processes.

Many manufacturers are working to optimize the process of stacking battery cells into modules because streamlining stacking can improve the throughput of the entire line. High-speed robotic handling systems, either delta robots or linear robots, are essential tools in this stacking process.

The Smart Function Kit for Handling, part of Bosch Rexroth's Smart MechatroniX family of plug-and-produce mechatronics systems, provides a flexible and efficient linear robot option for this challenge. It features the ctrIX DRIVE servo drive with integrated ctrIX CORE system control and an open interface to higher-level industrial networks.

Like the other Smart MechatroniX systems, it is truly "plug-and-produce": modern online tools support quick and intuitive component selection and configuration, and the pre-installed software allows for easier commissioning, supporting faster production start and helping speed to market.

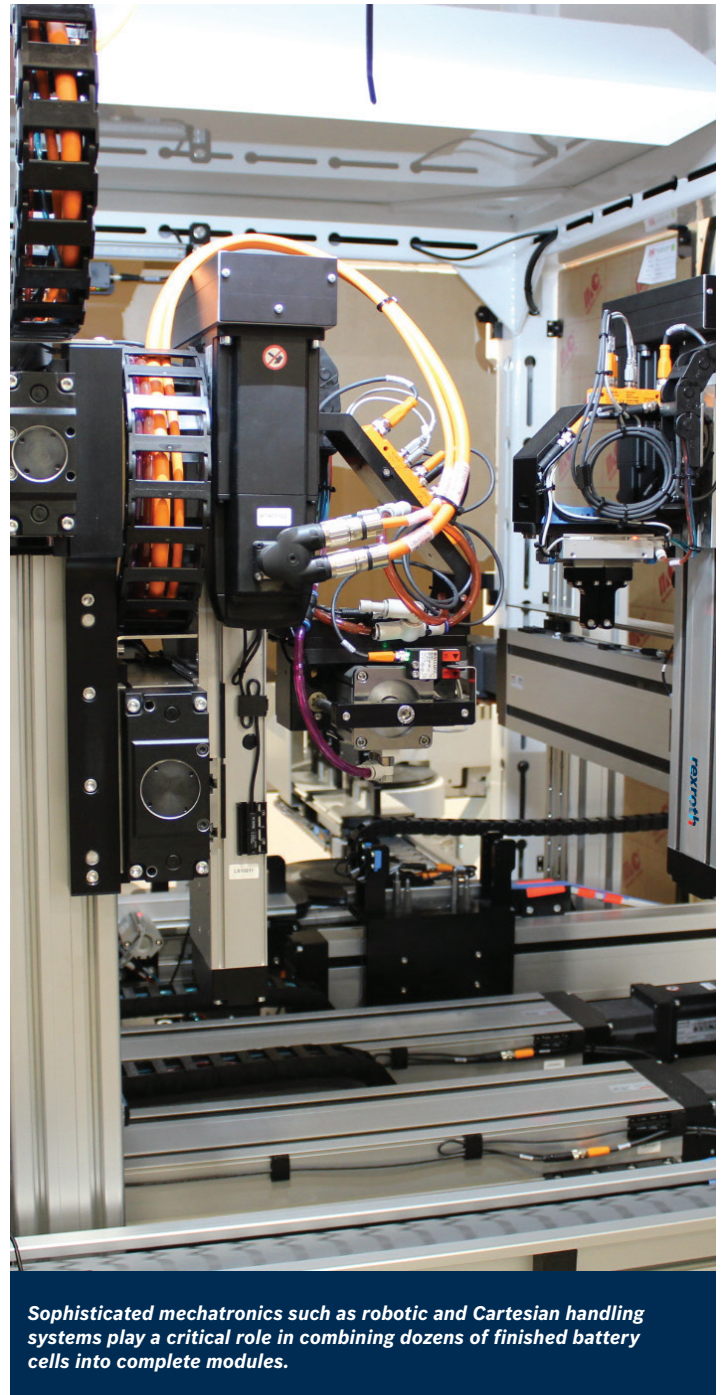
Rexroth's Smart Function Kits for Pressing and Dispensing offer precise operation and high throughput rates for module assembly steps such as:

- Adding electrolyte chemicals into each cell
- Pressing cell caps in place and welding them shut
- Adding positive and negative battery poles
- Wiring all the cells in the module together



Plug-and-produce Smart Function Kit for Handling

With the Smart Function Kits, drag-and-drop motion functions for these assembly tasks are easy to parameterize and program, regardless of the assembly application.



Sophisticated mechatronics such as robotic and Cartesian handling systems play a critical role in combining dozens of finished battery cells into complete modules.

Depending on the type of module being assembled, there are advantages to using manual assembly tools to complete certain processes. The latest generation of smart hand-held tools, such as the NEXO wireless intelligent nutrunner, has the controller integrated directly into the tool for greater efficiency and quality control. Available in pistol, right angle and custom output drive configurations, it features on-board analytics to allow detection of manufacturing issues such as defective studs, grounds, lugs and more.

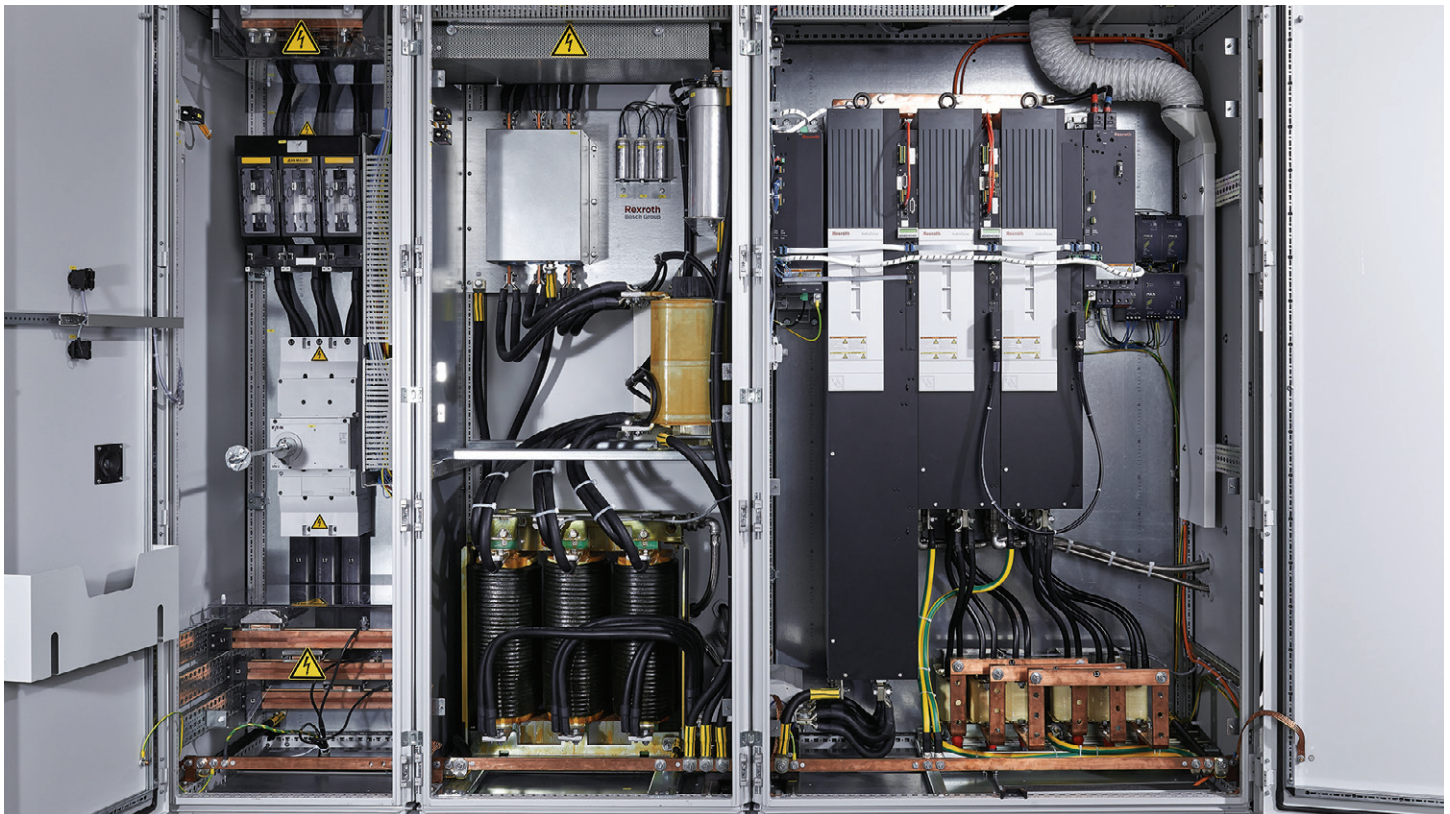
END-OF-LINE (EOL) TESTING

All these investments in improving the speed and efficiency of battery manufacturing will have less than optimal results if, at the end of the process, the batteries produced perform poorly once released into the marketplace. Regardless of the cell or battery produced, battery packs are complex devices, with power management systems, cooling technology and sensors integrated into the packs.

The final assembly, whether it's an EV battery pack or one destined for power grid storage purposes, needs to be fully tested as a final production step. In EV manufacturing, a plant producing 50 cars per hour needs to test a new battery pack every 72 seconds, so EOL battery-testing systems must be extremely reliable and highly automated to match assembly line production rates.

Bosch Rexroth's IndraDrive ML family of power converters provides very precise and accurate control during testing of the battery pack output by providing constant voltage, current and power according to the required test cycling. It features a scalable DC/DC drive design with the industry's smallest footprint, helping conserve valuable space in the control cabinet and, ultimately, product floor space.

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



End-of-line (EOL) battery testing platforms utilize systems such as Rexroth's IndraDrive ML family of power converters to provide precise, accurate power control during test cycling.



FOCUSED EXPERTISE TO ACCELERATE PRODUCTION

The demand for all types of batteries and power storage technology will only continue to accelerate. There are risks if battery manufacturers, in response to that demand, simply throw technology at their throughput challenges rather than planning, selecting and integrating the right technology and component choices to work together.

Bosch Rexroth can leverage its industry-leading automation portfolio and deep automotive manufacturing expertise to help prevent this risk. We draw on our deep, crossover expertise in battery production and automated manufacturing for a broad range of high-technology industries to expertly evaluate and solve complex automation challenges.

We also partner with leading automation engineering and factory integration specialists to find new ways to speed up machine and line designs. We use a concurrent engineering approach to conduct system design, programming and

component acquisition in tight, overlapping time frames to deploy complete automation solutions more rapidly. This methodology succeeds because we back it, and all our complete automation solutions, with global engineering, service and technical support resources.

MOVE FORWARD WITH BOSCH REXROTH

The right investments in technology, from electrode production through EOL battery testing, combined with the right automation technology supplier with the expertise to bring all the pieces together, can help ensure that production bottlenecks and inefficiencies are identified and eliminated. Bosch Rexroth is ready to apply our complete, industry-leading portfolio and deep expertise to help accelerate battery production and give manufacturers the tools they need to move battery manufacturing forward – fast.

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