

Exro Technologies

Overcoming Traditional 3-Phase Drive Limitations and
Introducing an Optimal Pairing for Magnet-Free Electric
Motors

MARCH 2024



OPTIMIZING POWER

MINIMUM ENERGY – MAXIMUM RESULTS

Who We Are

VISION

Create the most innovative power controls company that leads the transition to a sustainable electrified world.

MISSION

Utilize minimum energy with maximum results to expand the boundaries of control in e-mobility and energy storage.

At our core, **we are power electronics experts**. With our expertise we are bringing to market a **new generation of technologies** that fundamentally reshape **how the world consumes energy** in the **transportation and energy sectors**.



Exro Technologies

WHO WE ARE:

Power electronics experts.

WHAT WE DO:

Bring to market the next generation of inverter/BMS technologies that fundamentally change how the world consumes energy.

WHY IT MATTERS:

Our technologies expand the capabilities of electric motors and batteries to bridge the performance-cost gap and accelerate adoption towards a circular electrified economy.

WHERE TO FIND US:

Robust supply chain triangle spanning across North America.

 CALGARY, AB

 DEXTER, MI

 MESA, AZ



ISO 9001:2015



Independent Validation



NEMA Illumination Award
2022



Edison Award winner
2022



Innovation of the Year
Award winner 2022



Automotive News Pace
Award Finalist - 2023



Alberta Science Technology
Awards - 2023



Exro's Patented Coil Driver™: Solid State Coil Switching at Full Load without Torque Interruptions

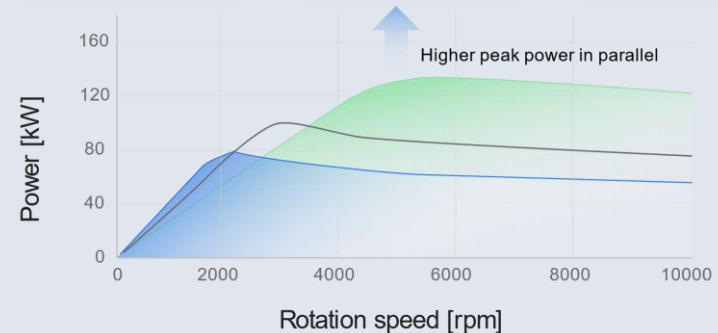
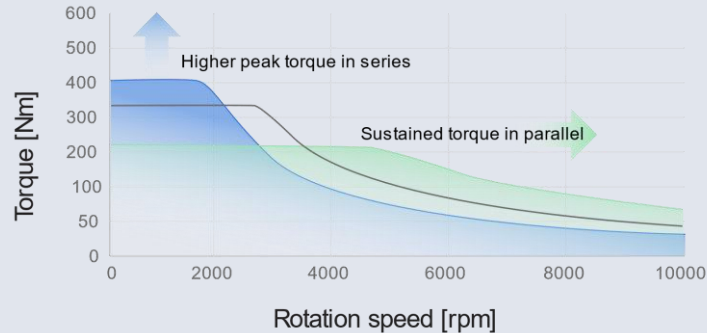
Coil Driver™ is an adaptive electric vehicle traction inverter that replaces the standard inverter in electric vehicles. The patented Coil Driver™ technology applies coil switching to increase torque at low speeds and enhance power and efficiency at high speeds.

In essence, the Coil Driver™ automatically selects between two modes in a single motor, minimizing the tradeoff faced in selecting between low-speed and high-speed operation.

EFFICIENCY ↑

TORQUE ↑

COST ↓



Series mode Parallel mode Standard 3-Phase Drive

Seamlessly maintaining higher torque density throughout vehicle operation leads to significant cost savings



BACKGROUND

Automotive: ICE

For combustion cars, the bulk of vehicle mass is steel and aluminum. Recycling rate for steel and aluminum in the automotive sector exceeds 90%.

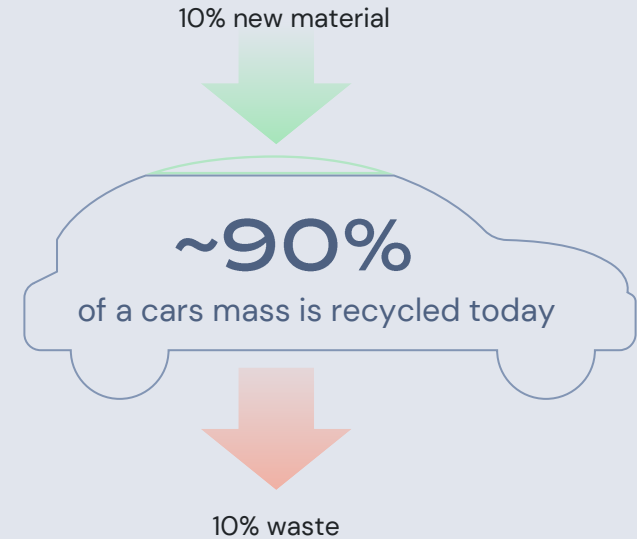
This is because steel, copper and aluminum remain as metal during the recycling process, saving

~95%

of the energy required to produce new materials.

Recycling steel, aluminum and copper can be performed with zero CO2 emissions if the heat source is carbon free.

Talking about “energy transition” sounds like a one-off event, the reality is this is a continuous building and dismantling of vehicles.



Readily recyclable materials must be part of this calculus if we are not to destroy the environment to save the climate.

BACKGROUND

Automotive: Electric

As we move toward electrification with the aim to eliminate CO2 emissions, we are adding new metals into the transportation eco system:

Lithium, Cobalt, Nickel, ...
in the batteries.

Neodymium, Dysprosium, ...
in the magnets used in the motors.

The challenge with these new materials is that they are not very easy to recycle.

This is primarily due to their reactivity; neodymium is one of the most reactive lanthanides, while not as reactive as lithium, it will oxidize in air and reacts slowly in cold water. Notably the oxide layer that forms on neodymium does not offer protection like it does with aluminum (another highly reactive metal). Instead, flaking off and newly exposing bare metal. Dysprosium while not as reactive as neodymium, will still oxidize in air, albeit more slowly.

This high reactivity means unless these metals are sealed and protected from air and moisture, they will rapidly form into oxides. Which means during recycling this protective barrier will likely get damaged, resulting the magnets oxidizing.

The other characteristic is that once these oxides form, they are very stable, which means they require a lot of energy to reduce them back to the metal.

The result due to this today less than 1% of the rare earths are recycled.
This is not what sustainable looks like.*



*note this is all rare earths, not just magnet materials.

What does a sustainable electric machine look like?

Copper and iron are metals that can be produced with zero carbon, are infinitely reusable and the only two materials we need to build great electric machines.

We don't need to, and arguably shouldn't use neodymium.

Electric Machine Types

AC Induction is:



SUSTAINABLE



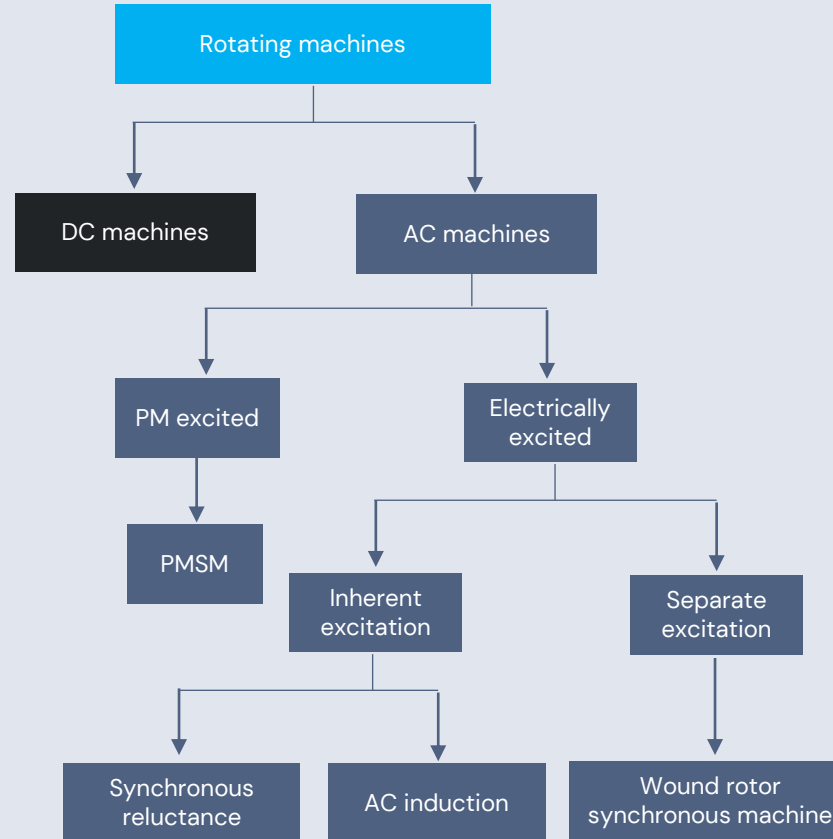
ROBUST



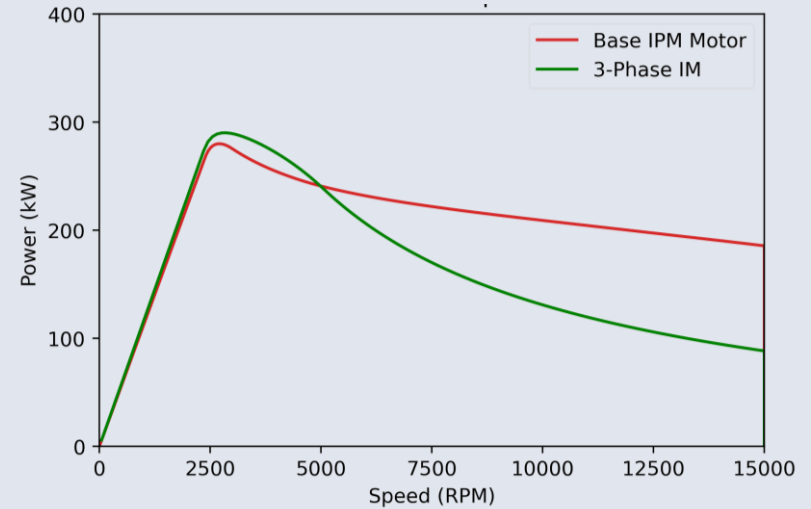
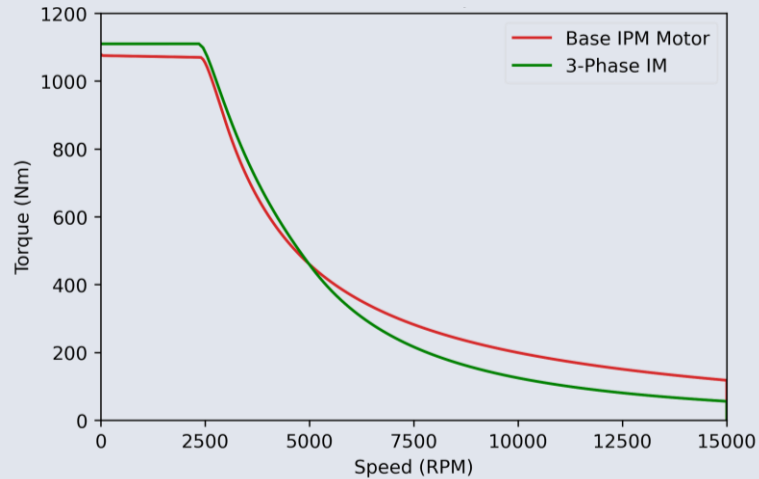
SIMPLE



COST-EFFECTIVE



Induction Machines: The Power Problem

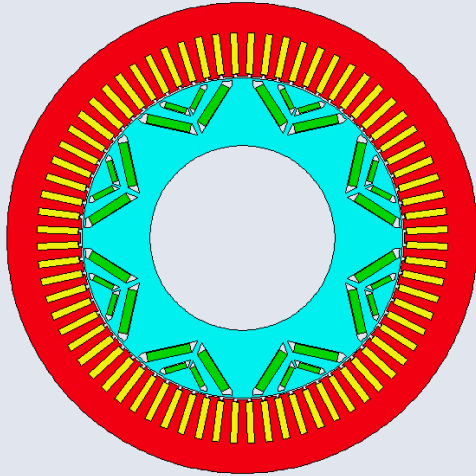


The induction machine with a standard 3-phase drive is not capable of maintaining power at speed.

Chevrolet Bolt

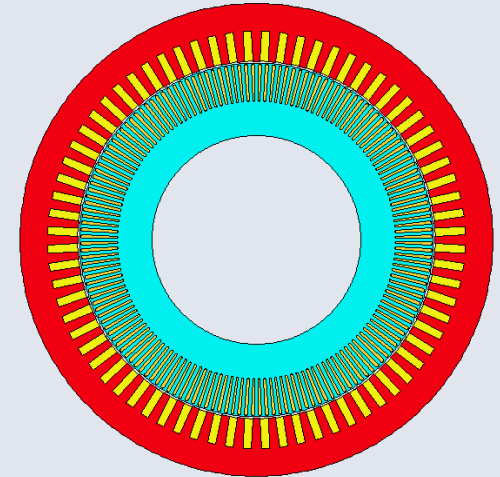
Case Study

GM Bolt IPM vs CD Driven Induction Machine



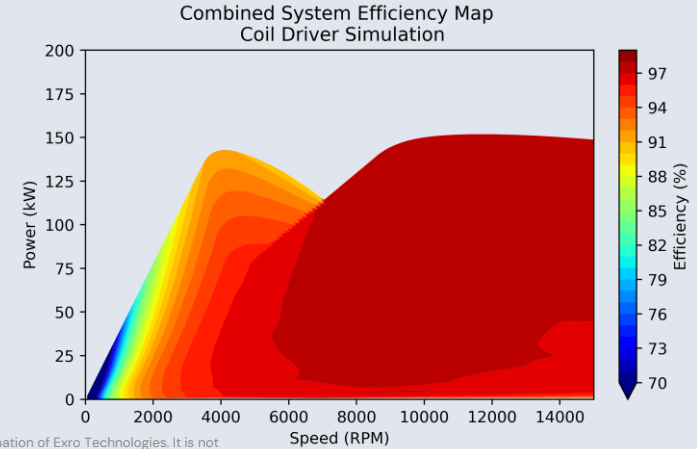
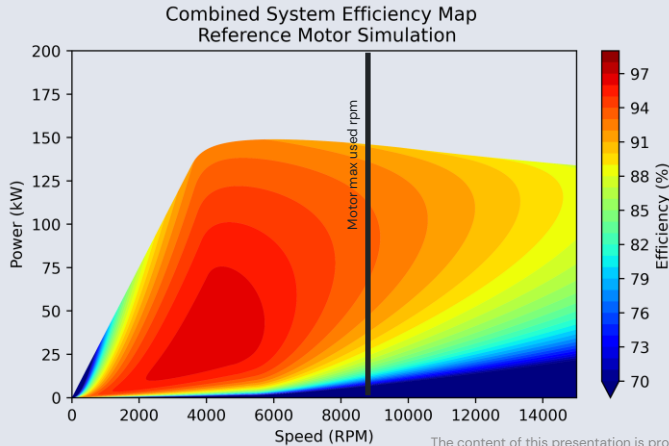
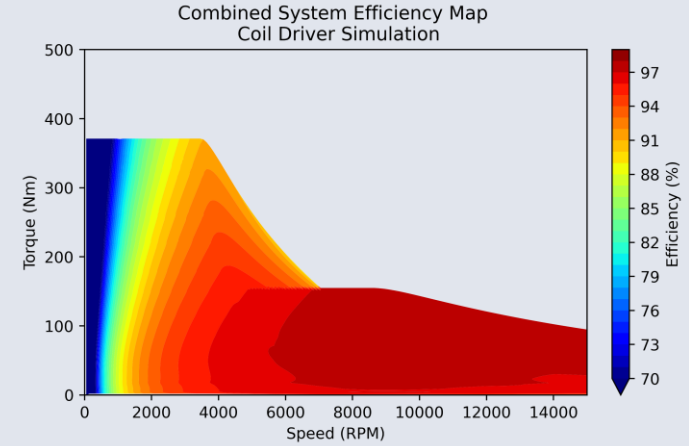
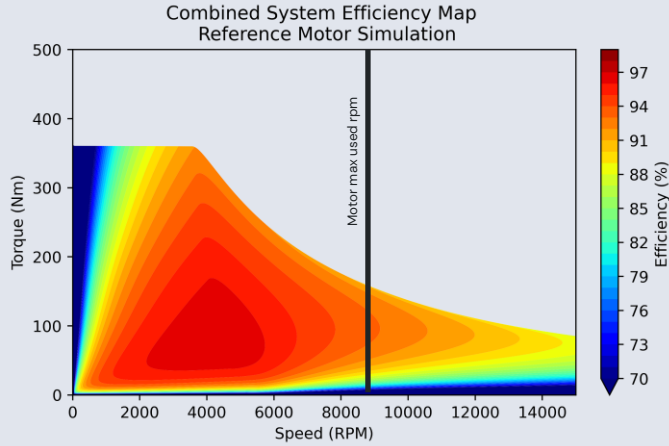
VS

204mm OD, 125mm stack	204mm OD, 125mm stack
8 pole 72 slot	8 pole 72 slot
170kVA inverter power	170kVA inverter power
24kg active weight	28kg active weight
1.5kg magnet	
2.8kg Cu	9.4kg Cu
19.7kg steel	18.6kg steel



Electric motor designs

Efficiency: GM Bolt IPM vs CD Driven Induction Machine



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Vehicle Assumptions

Parameter	Value
Mass	1628+75 kg
Final Drive Ratio	7.05:1 baseline IPM 12:1 CD induction
Wheel Radius	0.32 m
Frontal Area	2.4 m ²
Drag Coefficient	0.308
Friction Coefficient	0.014

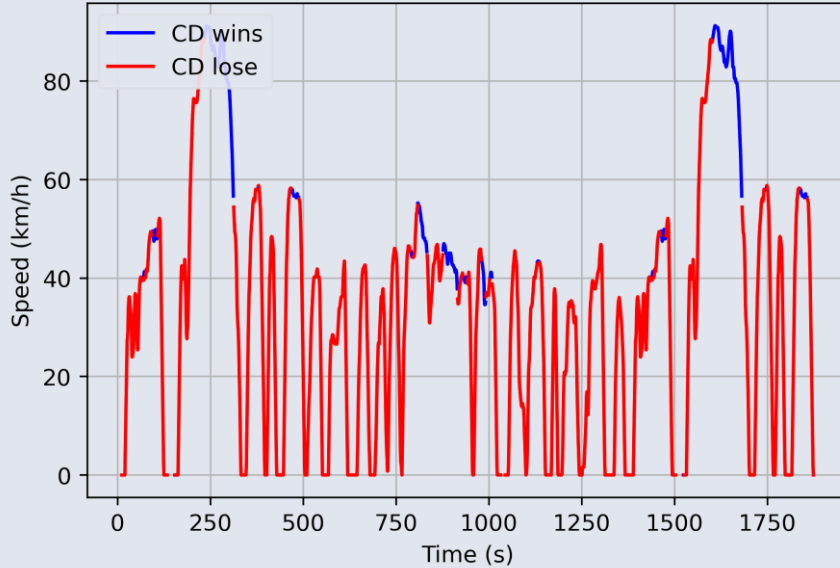


IPM max speed is 8810 rpm with 7.05:1 gives 1250 rpm axle speed
IM max speed is 15000 with 12:1 gives 1250 rpm axle speed

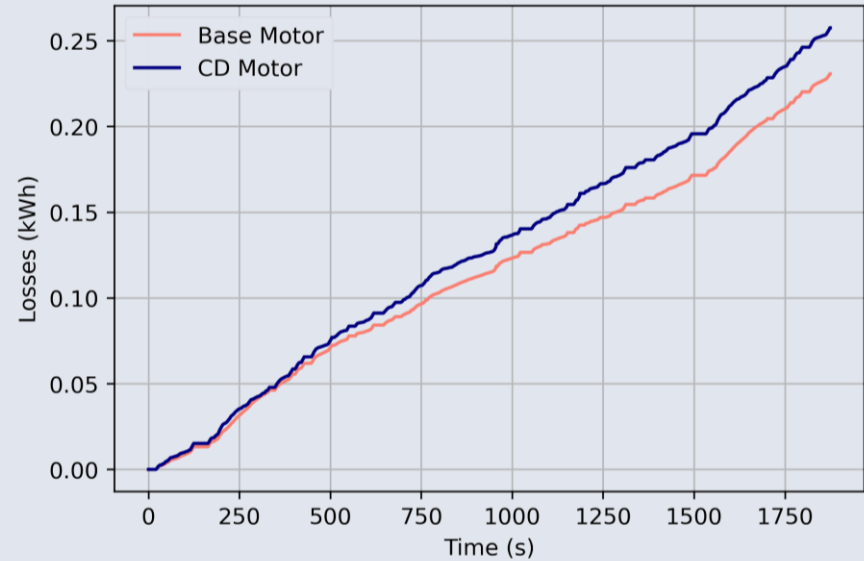


GM Bolt - FTP75 Drive Cycle

EPA FTP75 Driving Cycle



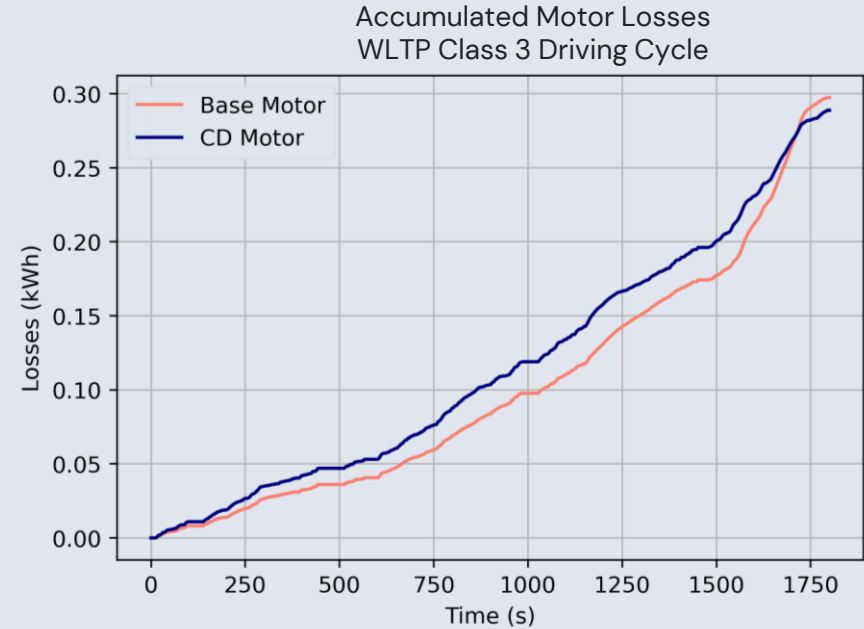
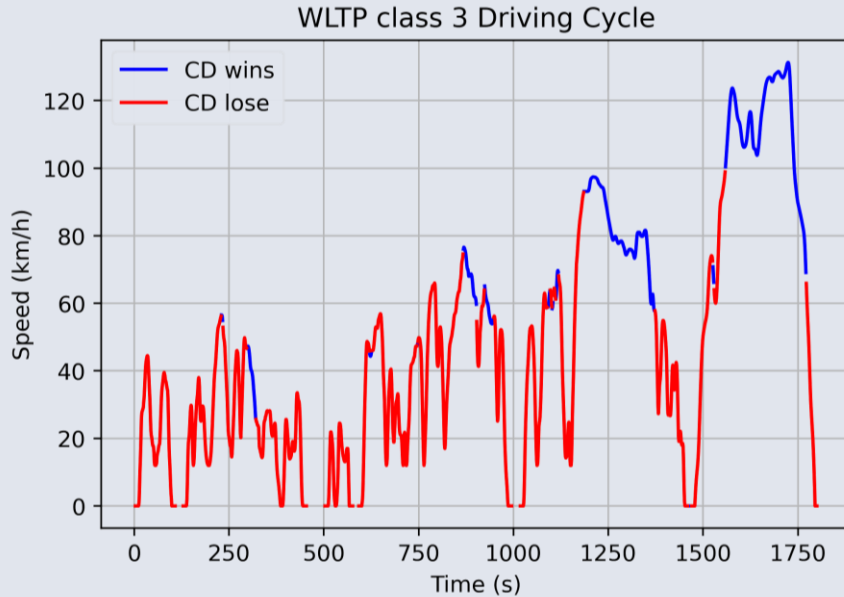
Accumulated Motor Losses
FTP75 Driving Cycle



WLTP Class 3	Total Losses			Cycle Efficiency		
CD Gear Ratio	Baseline	Coil Driver™	Difference	Baseline	Coil Driver™	Difference
7.05:1	0.2308	0.3899	-68.97%	88.34	81.77	-7.38%
12:01		0.2576	-11.63%		87.16	-1.25%



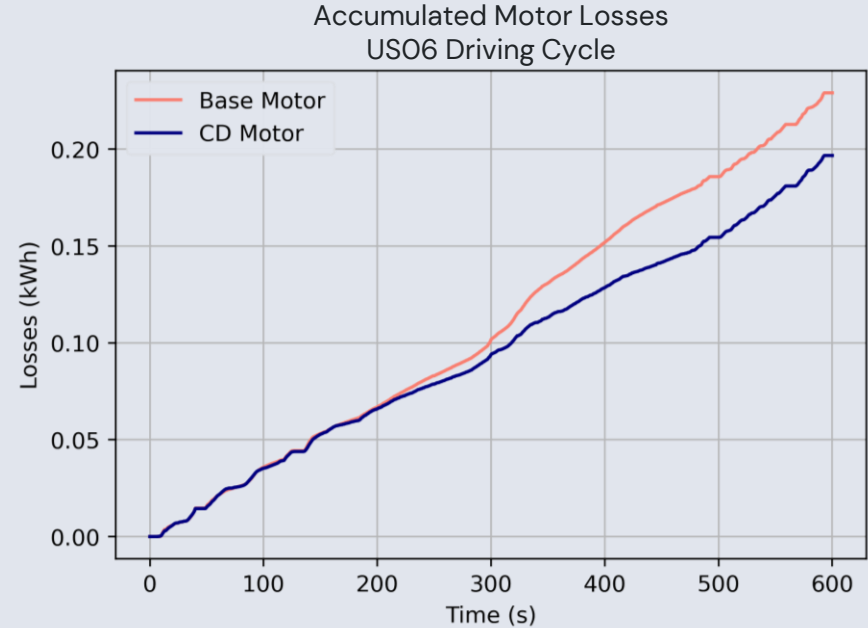
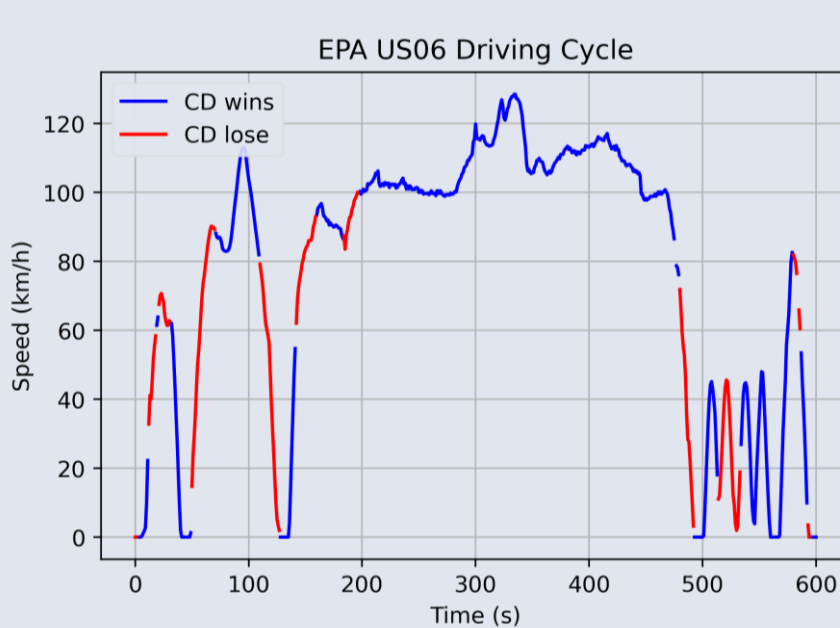
GM Bolt - WLTP Class 3 Drive Cycle



WLTP Class 3	Total Losses			Cycle Efficiency		
CD Gear Ratio	Baseline	Coil Driver™	Difference	Baseline	Coil Driver™	Difference
7.05:1	0.2974	0.3787	-27.34%	91.18%	89.03%	-2.33%
12:01		0.2888	2.89%		91.41%	0.25%



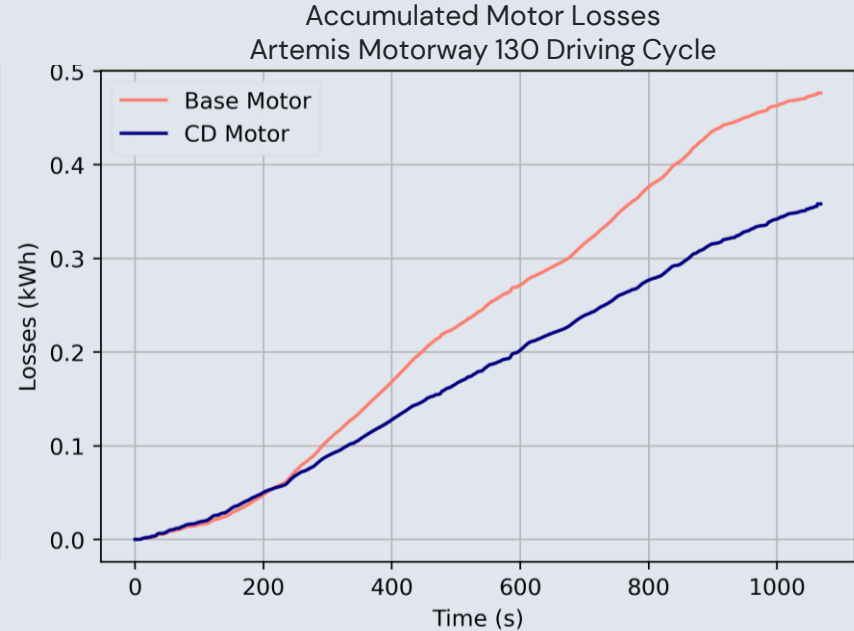
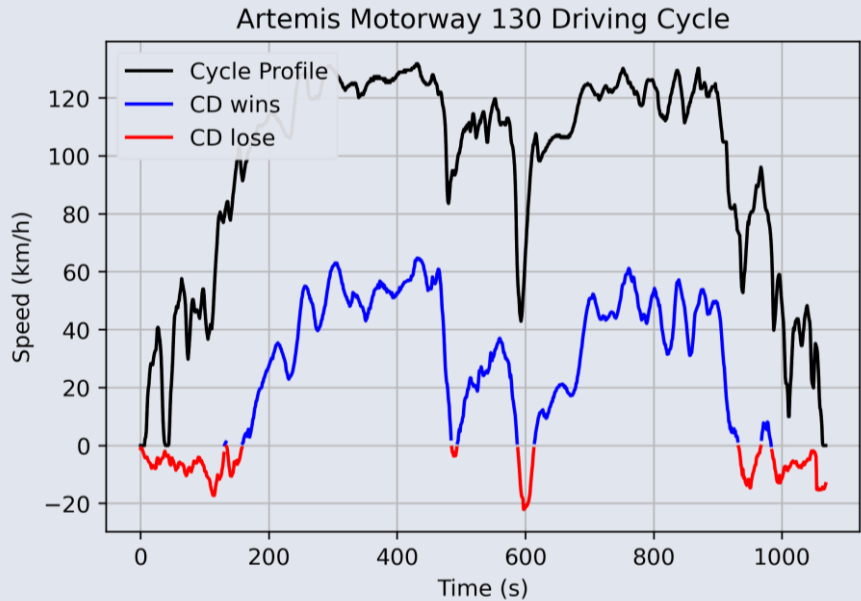
GM Bolt – US06 Drive Cycle



WLTP Class 3	Total Losses			Cycle Efficiency		
CD Gear Ratio	Baseline	Coil Driver™	Difference	Baseline	Coil Driver™	Difference
7.05:1	0.2291			90.20		
12:01		0.1967	14.13%		91.47	1.31%



GM Bolt – Artemis Motorway 130 Cycle



WLTP Class 3	Total Losses			Cycle Efficiency		
CD Gear Ratio	Baseline	Coil Driver™	Difference	Baseline	Coil Driver™	Difference
7.05:1	0.4766			92.04		
12:01		0.3582	24.85%		93.90	1.95%



The Coil Driver™ Impact

Simulations show AC induction +
Coil Driver™ increases performance

Benchmarked against Chevy Bolt using
Industry standard drive cycles

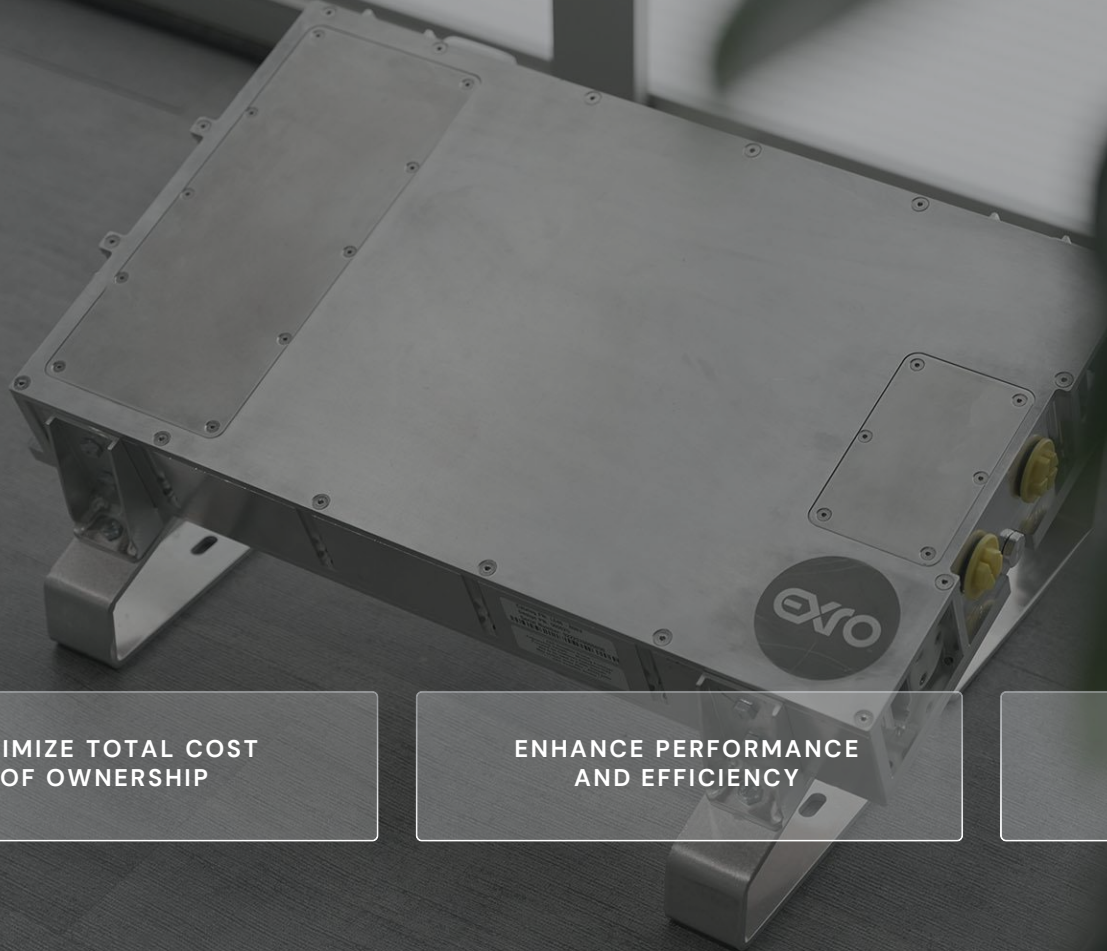
*Rare-Earth-Free AC Induction + CD Surpassed IPM
Where Efficiency Matters Most – High Speed Highway Driving*

*The Coil Driver™ enables low cost, robust, rare-earth-free AC induction motors to
meet performance requirements of various vehicle applications.*

Standard 3-phase drives CANNOT achieve this!



Coil Driver™ Technology



**MINIMIZE TOTAL COST
OF OWNERSHIP**

**ENHANCE PERFORMANCE
AND EFFICIENCY**

**REDUCE RELIANCE ON
RARE EARTH METALS**





Exro Technologies Inc.
www.exro.com | @exrotech