Anatomy of Electric Vehicles by Land, Water and Air

By Dr Peter Harrop
IDTechEx

www.IDTechEx.com

North America	Europe (UK)	IDTechEx (Germany)
IDTechEx, Inc.	IDTechEx Ltd	Louisenstr. 7a
Suite 0222	Downing Park, Station Road,	01099 Dresden
222 Third Street	Swaffham Bulbeck,	Germany
Cambridge MA 02142	Cambridge CB25 0NW	
United States	United Kingdom.	
Tel: +1 617 577 7890	Tel: + 44 (0) 1223 813703	Tel: +49 371 36777 643
Fax: +1 617 577 7810	Fax: +44 (0) 1223 812400	Fax: +49 371 36777 639

US Tel: +1 617 577 7890
UK Tel: + 44 (0)1223 813703
www.IDTechEx.com

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1. Anatomy of Electric Vehicles by Land, Water and Air

The nomenclature is horrific. Many words describing types of electric vehicle or their components mean the same thing yet some acronyms mean several, very different things. The fog thickens when you realise that manufacturers of both the vehicles and their components have an irritating habit of making false and misleading claims. This white paper consists of a searchlight focussed on the various types of electric vehicle and their components in particular, how these go together and what aspects really matter. If you emerge stumbling more confidently in no more than a mist then we shall have achieved our objective.

1.1. Anatomy of the vehicle

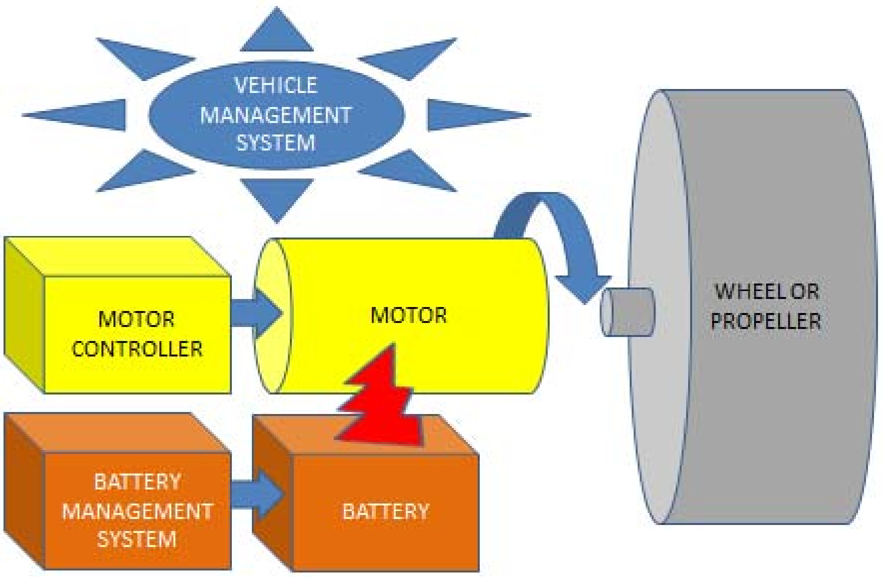
At its simplest, an electric vehicle uses an electric motor powered by something on board – usually a battery – to make it go along by means of a wheel or a propeller. A pure electric vehicle works like this all the time. A hybrid electric vehicle has a non-electric engine in addition to the motor. This may sometimes work alongside the electric motor - a parallel hybrid - or it may do nothing more than charge the battery, in which case it is appropriately named a range extender in a series hybrid, this being the favoured option these days as hybrids become more like pure electric vehicles. Range extenders are mainly small piston engines specifically designed for the job but rotary combustion engines, mini turbines (jet engines burning almost any fuel) and fuel cells also have a place.

Fig. 1.1 *Boeing fuel cell aircraft trial*

Source Boeing

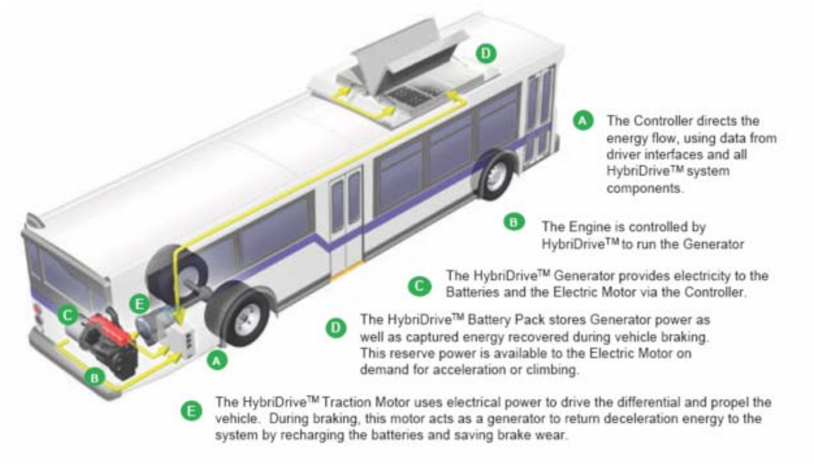
However, all electric vehicles need a vehicle management system VMS – basically electric and electronics that coordinates operation of the various items of hardware to ensure safety, efficiency and the required performance. In fact, the more you look, the more you see. The VMS interacts with a Battery Management System BMS that specifically manages the input, output and safety of the battery cells. The VMS also interacts with the motor via electronics and electrics called the Motor Controller and it typically links to an onboard slow charging system as more vehicles can be plugged in overnight to get electricity at one fifth of the cost of gasoline. The following pictures show variants on this.

Fig. 1.2 *The anatomy of a pure electric vehicle*



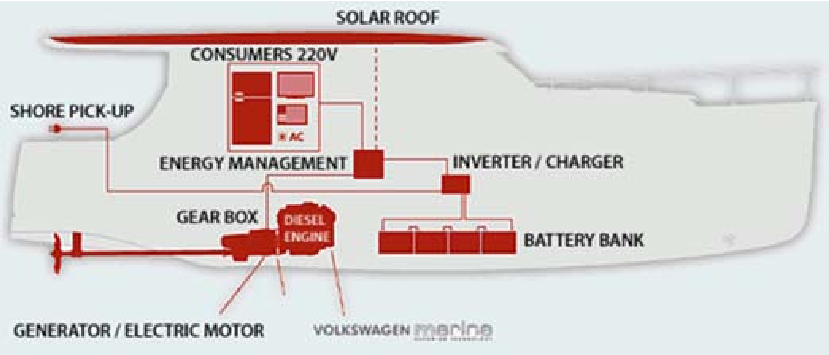
Source IDTechEx

Fig. 1.3 *A hybrid electric vehicle, the Orion VII bus with BAE Systems Hybridrive™ powertrain*



Source Orion

Fig. 1.4 *Greenline 33 hybrid boat with 7kW electric motor*



Source Greenline

It is tempting to think of the motor and the battery as the important devices, the electrics and electronics being there as something of an afterthought to improve things a bit at the margins. Nothing could be further from the truth. With some motors, an inadequate motor controller can make the motor spin faster and faster until it explodes, or let it burn out under heavy loads as when going up a hill. An inadequate battery controller can make an otherwise satisfactory bank of cells explode or catch fire since there is no such thing as an inherently safe battery cell. Then there is cost. The BMS and packaging can be up to half the cost of the battery pack, matching the cost of the cells.

Most electric vehicles either use lithium-ion rechargeable batteries or have them as an increasingly popular option. The typical cost structure of a pure electric vehicle with lead acid batteries is very different from that of one with lithium-ion batteries as shown below.

Table 1.1 *Typical cost structure of pure electric vehicles as % of total*

Example	**Motor cost %**	**Battery cost % and type**	**Other %**	**Total**
Electric bike	17	30 lead acid	30	100
Car	6	50 lithium-ion	40	100

Source IDTechEx

1.2. Choices of motor

It is a testimony to the excellence of electric motor design and manufacture that these motors are almost never the main governing factor in the cost, loss of useful space, reliability or life of an electric vehicle and usually the performance of the motor is less of a worry than factors such as battery charge-discharge rate, cost, life, safety and capacity. Thus the term, "The battery is the car". All the same, the huge growth of the electric vehicle market, the energetic competition and the rapid widening of applications leaves the electric motor designer with much to do and new models are appearing all the time. Indeed, progress with electric motors feeds back into vehicle design as with the trend, by no means universal, to high speed high voltage motors and systems in such vehicles. There are many niche applications for the smaller participants, so new motor manufacturers continue to enter the business. There are many types of electric motor but only a few of them are suitable for providing the strong surges of power required in an electric vehicle. One choice is between those with contacts called brushes that press on a rotating set of contacts in the motor and brushless motors.

1.2.1. Brushed versions are losers

The balance of advantages and disadvantages of brushed traction motors in an industry demanding much improved performance is increasingly unimpressive as shown below.

Table 1.2 *Advantages vs disadvantages of brushed vs brushless vehicle traction motors for electric vehicles.*

Advantages	**Disadvantages**
Mass production Easy to understand and integrate	Problems of sparks, dust, reliability, electromagnetic interference and acoustic noise generated. Short life. Bigger than some alternatives. For pedal bikes they cause drag.

Source IDTechEx

Motors with brushes are gradually being abandoned, with the ones used by hobbyists and those in electric bikes in China being among the last to go because here low up front cost and easy integration into a vehicle are usually paramount.

1.2.2. Asynchronous and synchronous battling it out

Of the brushless motors now favoured for electric vehicles there are the asynchronous and synchronous ones. Asynchronous means that the mechanical rotation is not synchronous with the electrical rotation: there is some slip (a few percent) necessary to induce the rotor current. Sometimes such motors are called AC induction or just induction and basically they are rotating transformers. They have most of the market for motors that take a lot of punishment and need the highest power. One can express this as over 10kW and often hundreds of kilowatts rated power and torque that can be hundreds on Newton meters. Think large buses, trucks and military vehicles and heavy lifting as with mobile cranes and forklifts. Traditionally, asynchronous traction motors are rather large and inefficient but very rugged, tolerating wide ranges of temperature with no maintenance and promising low price because they employ copper wire and even lower cost materials.

Contrast synchronous motors which have – you guessed it - mechanical rotation synchronous with electrical rotation. These have traditionally been down to half the size because they usually use permanent magnets but that puts the cost up. Now some misleading jargon. There are two favoured types. The Permanent Magnet AC motor uses a sine wave and the Brushless DC motor BLDC uses a trapezoidal wave to similar effects. They are used in much the same types of electric vehicle such as those with in-wheel motors. Call that a hub motor when it is in an electric bike – now a common sight. They are used for best acceleration and best economics below 5kW or so. They are seen in cars and golf cars but improved asynchronous ones are taking some of these applications as well. They are seen in mobility vehicles for the disabled, in Autonomous Underwater Vehicles AUVs, surface boats, electric aircraft and off-road vehicles such as All Terrain Vehicles ATVs and quad bikes.

Table 1.3 *The main choices of electric vehicle traction motor technology over the next decade.*

Type	**Sub type**	**Permanent magnet**	**Can work in reverse to grab back up to 20% of energy during braking**	**Market position in terms of money spent**	**Increasing market share**
Asynchronous		No	Yes	2	Yes
Synchronous	BLDC ie PMAC	Yes	Yes	1	Yes
	Switched reluctance	No		4	Yes from a tiny base
	Brushed DC	No		3	No

Source IDTechEx

Let us look at this in more detail. Electric vehicles have a huge variety of duty cycles, from the gentle movement of a mobility vehicle for the disabled to the huge power needed from start by a tugboat or bulldozer. Indeed, some electric vehicles never exceed 4 kph whereas others seek to set records at 400 kph. Some require the motor to fit in a small space such as a car wheel yet for others there is plenty of space as in a boat. In certain applications, power to weight ratio is very important as with aircraft. Consequently, it is no surprise that there is no one motor type let alone model that can serve all purposes. Perhaps more surprising is the fact that identical applications are variously served by both asynchronous and synchronous motors. Examples are sports cars and the airliner that becomes an electric vehicle when on the ground thanks to an electric motor in the nose wheel. This is because the technologies are advancing rapidly and different price-performance compromises are chosen. In interviews carried out for the IDTechEx report, “Electric Motors for Electric Vehicles 2012-2022”, many respondents felt that it is as yet uncertain whether the current dominance of synchronous permanent magnet motors will continue whereas a significant number believe that asynchronous motors without permanent magnets will take the majority of the global electric vehicle electric motor market by value, land, water and air. Our own opinion is that asynchronous motors will continue to increase their minority market share over the coming decade. Land applications, particularly on-road applications and specifically cars will dominate the expenditure on EV traction motors but the highest percentage profits will not be made by making car electric motors.

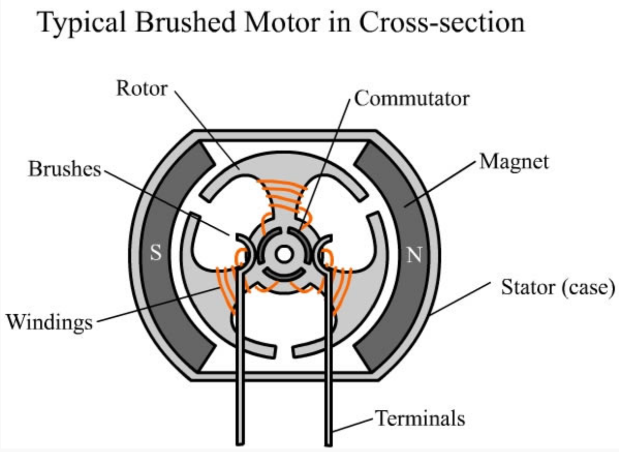
The battle for supremacy by different motor manufacturers and motor types will be fought primarily on the price-performance compromise, not the presumed scarcity of certain materials such as neodymium for permanent magnet versions. The life and reliability of the motor is not a primary determinant of market success, given that the synchronous versions that use “brushes” to a commutator are rapidly losing market share and all other versions AC and DC, synchronous and asynchronous are brushless. In line with trends elsewhere in manufactured products, electronics and electrics increasingly replace mechanics. The controller replaces the brushes by picking up a signal from the hall effects sensor on the motor, which tells the controller where the rotor is, so the controller knows how to make the rotating magnetic field. As a major exception, brushed motors retain major market share with e-bikes in China because here price is paramount.

A more detailed comparison of traction motor options is given below.

Table 1.4 *A comparison of potential and actual electric traction motor technologies is given below.*

Type	Advantages	Disadvantages and challenges sometimes encountered	Typical Drive
Asynchronous ie AC polyphase induction eg squirrel-cage. A rotating copper wire transformer	No precious metals, no servicing, simple parts, spin up from zero to 13,000 rpm without transmission. Long life, high reliability. Rotation in-sync with frequency - hence no slip. Regenerative braking without expensive extras (actually also available in PMAC & BLDC), simple electronic reverse, integrated components (main contactors and DC-DC converter), ability to adapt exact characteristics of the motor (and also throttle and brake potentiometers parameters, battery and other hardware parameters) via software, lack of brushes, high top RPM limit (eg 10,000), water cooling where needed and high reliability.	Starting inrush current can be high. Speed control requires variable frequency source. High voltage can mean greater insulation needed. Cost of electronic controllers. Batteries produce DC so installation is more complex. Top shows asynchronous bus motor and bottom shows asynchronous motorcycle motor with controller.  	Poly-phase AC, variable frequency AC

Type	Advantages	Disadvantages and challenges sometimes encountered	Typical Drive
	Potentially highest power to weight ratio as converters are simplified. Not all these benefits are unique however.		
Brushless DC BLDC or PMAC. Rotor spinning with coils passing magnets at the same rate as the alternating current and the resulting magnetic field which drives it.	Very low electromagnetic interference (EMI) long lifespan, low maintenance, high torque, high efficiency compared to brushed versions. Regenerative braking without expensive extras. In a permanent magnet motor, the rotor's magnetic fields are created by rare earth neodymium permanent magnets, and only the stator has to create a rotating electromagnetic force (or more rarely vice versa). This results in higher efficiency. The magnets are able to provide high torque. Efficient at low speed	Must slip in order to produce torque. High initial cost. Cost of electronic controllers Magnets can be destroyed by temperature and degrade over time. Magnets do not transmit heat well, leading to heat build-up in the windings. This means that the continuous operating power of PM motors is often substantially less than the peak.  	DC
Brushed DC	Readily available, simple to install, simple and inexpensive control, low cost. DC motors permit overdrive up to a factor of 10-to-1 for short periods of time. For example, a 20,000-watt motor will accept 100,000 watts for a short	Relatively inefficient. Too much overdriving causes heat build-up in the motor and the motor heats up to the point where it self-destructs. Often high current, thick wire. Dust, noise, sparks inferior reliability and life, maintenance needed. Speed torque curve not as flat as brushless alternatives so less ideal for operation at all speeds.	DC

Type	Advantages	Disadvantages and challenges sometimes encountered	Typical Drive
	period of time and deliver 5 times its rated power. This is useful for short bursts of acceleration. Dc motors can have extremely high peak power so they are preferred for drag racing.		
Switched reluctance motor SRM (other variants and names include Synchronous reluctance motor, variable reluctance motor, switched reluctance motor)	A reluctance motor is a type of electric motor that induces non-permanent magnetic poles on the ferromagnetic rotor. Torque is generated through the phenomenon of magnetic reluctance. Reluctance motors can have very high power density at low-cost, making them ideal for many applications. No magnet. Simplicity, Tolerant of hostile environments. Wide constant power speed range. No magnetic drag losses at low torques, low active material cost. High system efficiency over a wide range of torque and speed, stable and application friendly , simple and rugged electronic controls,	Size, acoustic noise, torque density has been less than PM with comparable cooling but parity is now claimed. Electronics popularly believed to be complex and expensive but this is now disputed. Disadvantages are high torque ripple when operated at low speed, and noise caused by torque ripple though the Renault Fluence electric car is quiet despite using a Continental SR motor. Until recently, their use has been limited by the complexity inherent in both designing the motors and controlling them. These challenges are being overcome by advances in the theory, by the use of sophisticated computer design tools, and by the use of low-cost embedded systems for motor control. These control systems are typically based on microcontrollers using control algorithms and real-time computing to tailor drive waveforms according to rotor position and current or voltage feedback. 	AC

Type	Advantages	Disadvantages and challenges sometimes encountered	Typical Drive
	fault tolerance and benign fault modes , inherent regen, robust, no magnets, windings or conductors on the rotor. Lowest construction cost of any industrial electric motor because of its simple structure. Phase windings electrically isolated from each other, resulting in higher fault tolerance compared to inverter driven AC induction motors. The optimal drive waveform is not a pure sinusoid, due to the non-linear torque relative to rotor displacement, and the highly position dependent inductance of the stator phase windings.		

Source IDTechEx

Permanent magnet motors can have the magnets in the stator or rotor. Indeed, the rotor can be inside or outside. An example and a comparison are shown below.

Fig. 1.5 *Bicycle hub motor rotor left and stator right.*

Source Library

Table 1.5 *Comparison of outer - rotor and inner - rotor motors*

Outer Rotor	Inner Rotor
Greater rotor inertia	Lower rotor inertia
Less torque perturbation	More torque perturbation
Slower acceleration	Fast acceleration
Lower-energy magnets can be used	Higher energy magnets required
Poor heat dissipation	Very good heat dissipation
Poor tolerance of high side load	Good tolerance of high side load
Reversibility can be problematic	Reversibility good

Source IDTechEx

1.2.3. Axial flux vs radial flux motors

99% of electric motors are barrel shaped with the magnetic flux axially oriented. However, the original Faraday radial flux motor is coming back.

For example, the IMT motor is a single sided axial flux permanent magnet PM brushless motor with a slotted iron stator. Such axial flux motors are disc shaped, rather than the more commonly available drum shape that is typical of radial flux motors. The disc shape is the result of the stator and rotor being placed adjacent to each other rather than the rotor spinning inside the stator cylinder. Axial flux motors are usually described by industry as axial air gap or "pancake" motors. Increased availability and reduced cost of both power electronics and magnetically strong materials (such as neodymium iron boron) has enabled the development of the IMT motor design, for example.

The combination of these technical advances allows dramatic improvements in efficiency (particularly of small machines) and/or variable speed drives that remove the need for geared transmissions in some applications. It is also a convenient shape for in-wheel motors. IMT even claims:

- High torque from zero speed
- High efficiency throughout speed range
- Smaller size
- Lower cost in volume than competing technology

Fig. 1.6 *Axial flux in-wheel motor driving a bicycle and a propeller.*

Source IMT

1.3. Sophisticated motors bridging gaps in performance

Increasingly, there are electric traction motors designed to one principle but modified to overcome many of the disadvantages of that option. Here are two of them.

1.3.1. Advanced asynchronous motor variant – Chorus Motors

The new Chorus Meshcon motor's "mesh-connected" winding is unique. “A Chorus drive offers higher efficiency, smaller size and weight, very high startup torques, greater continuous torque, and greater reliability. In a normal 3-phase motor, failure of a single phase means the motor cannot start itself. Damage to a single phase in a multi-phase Chorus drive will only slightly reduce efficiency; this is another major improvement over conventional 3-phase AC motors.”

Fig. 1.7 *60/15 kW Chorus Meshcon motor*

Source Chorus Motors

The Chorus Motor's patented employment of electrical drive harmonics unlocks a power-to-weight ratio of almost 10:1 over conventional AC induction solutions. This very high power density, and the use of patented control logic, allows the motor to function efficiently in both low-speed/high-torque and high-speed/low-torque configurations. In other words Chorus handles very fast starts and 'power jumps' as well as smooth, continuous high-speed operation with equal elegance.

A Chorus drive is a high phase order induction machine. The stator has extensive pole changing capabilities, which allows the stator to generate any 4n+2 or 4n number of poles up to the slot count, with certain machine symmetry limitations. Because of induction machine scaling laws, the pure pole changing capability is of limited usefulness, higher pole count machines have smaller poles, and thus have greater magnetization losses. The primary benefit of the pole changing capability is that the drive phase relationships used to produce the pole changing effect are precisely the same phase relationships found between the harmonic components of the drive waveform. If one considers the drive waveform to be the desired fundamental with superimposed harmonics, one finds that the rotating field produced consists of the desired base pole count with superimposed higher pole count rotating fields. In contrast to a conventional 3-phase machine, these harmonic rotating fields rotate in synchronism with the desired fundamental rotating field.

The efficiency loss associated with harmonics in the drive waveform is thus greatly reduced, and various engineering compromises made in order to reduce harmonic content may now be shifted in the direction of increased harmonic content. For example, the PWM base frequency may be substantially reduced.

As a high-phase order motor, the amount of current running through each phase is reduced, enabling a 20-30% reduction in the size and weight of the power electronics module. Chorus Meshcon is competitive at applications down to fractional horsepower, including some very high starting torque servo applications. Initial test units are in the 1.5-20 hp frame size. The technology becomes increasingly dominant as the motor size grows, because electronics costs are more significant in very large motors than in very small ones.

Chorus Meshcon is considerably less expensive to mass produce than a 3 phase induction drive with the same performance. It is also far less expensive than any brushless DC solutions, because Chorus Meshcon does not require the use of any expensive rare earth materials for magnetization. Chorus Meshcon is far cheaper for traction applications because we require much less power electronics to do the same job. Power silicon is expensive. Second, there are other cost advantages in using the Chorus high phase order drive approach. Any AC induction frame can be rewound to a Chorus Meshcon configuration. All components used in Chorus Meshcon are available off-the-shelf today – the genius of Chorus Meshcon is that a different configuration of the same components provides far greater benefits. What this means is that the cost of adapting existing induction machines to a Chorus Meshcon approach are minimal. Chorus is inherently tolerant of harmonics – including saturation harmonics. This means that not only can the drive produce more output at low speed than that same drive in a 3 phase configuration, but the motor can handle far greater power at low speed and in overload before overheating.

Most AC induction motors now in use are 3-phase ("polyphase") machines. Each phase acts at a different angle from the others, so they work together to turn the rotor of the motor. Along with the main wave pattern (called "the fundamental"), there are accompanying repetitive complex waveforms called "harmonics". In a conventional electric motor, these harmonics act as a brake on the main wave. Harmonics slow down conventional electric motors and they limit the amount of power a motor can efficiently use to generate rotational force (called "torque"). The principal technical advance of the Chorus technology is that harmonics are co-opted and enlisted to act in concert with the fundamental. Instead of acting like a brake as in the conventional 3-phase motor, the harmonics are now used to drive the Chorus motor alongside the fundamental frequency. The most stunning breakthrough of the Chorus technology is that it changes what was a braking force into an additional driving force. Heat produced by an electric motor is energy that was not efficiently converted into motion. Efficiency and heating problems tend to set the limits of continuous power output on a variable frequency drive. The new Chorus motor is much more efficient, and produces less heat, than a variable frequency drive; and can have a commensurately higher continuous torque output.

Furthermore, for short time periods, a Chorus motor provides 3 to 5 times the peak torque of a conventional drive. Peak torques are used when motors require extra power for short amounts of time for things like starting and stopping, or adjusting rapidly to changes in load.

Borealis' first Chorus technology patent was issued April 25, 2000, and several more patents have since been issued. A working 18-phase prototype demonstrates the advantages of the technology in head-to-head tests against standard 3-phase motors. Operating the Chorus drive with a square wave drive results in a greater RMS voltage output from the inverter for the same DC link voltage. This means that the motor will be operated at a higher voltage and a correspondingly lower current, enabling the same power electronics to provide greater motor power at a fixed DC link voltage. This higher power may either be in the form of increased constant torque speed, or if the motor is wound with a greater number of turns, greater peak torque capability. The motor continuous torque rating is set by heating and thus slot current; if the number of turns is increased then smaller wire would need to be used, and while the inverter would thus be capable of greater overload torque, the motor would have essentially unchanged continuous torque. The Chorus motor design makes better use of slot copper. In a conventional 3-phase machine, individual slots carry halves of two separate windings, often windings from different phases. The

RMS slot current is not simply the RMS winding current times the number of turns, but something less than this. A Chorus drive provides greater net slot current for the same winding current, resulting in greater MMF for the same copper losses, and thus greater efficiency. For the same RMS applied voltage, Chorus motor windings have fewer series turns for reduced copper losses.

1.3.2. Advanced synchronous PM motor – Protean Electric

“Protean Drive is self-contained, in-wheel motor technology. Each DC-powered motor includes a built-in inverter, power electronics and software, as well as liquid cooling ports. Probably the most unique aspect is that each motor in this F-150 application has eight sub-motors,” Tom Prucha, Principal Applications Engineer for Protean Electric in Troy, MI. said. The eight sub-motors can operate together or in any combination. “This setup provides redundancy. So if one of the eight sub-motors fails, the other seven can continue to operate. The sub-motor concept also facilitates operating at optimum efficiency. For instance, if the vehicle is operating at a speed and load below the efficiency map’s sweet spot, software controls can temporarily turn off a sub-motor so that the remaining sub-motors have to work harder—putting those sub-motors into a sweet spot for a net gain in efficiency,” explained Prucha. The sub-motor concept and the stator design facilitate automated assembly.

“By partitioning the motor into sub-motors, we can use smaller devices that are better suited to automated assembly techniques. The proprietary methodology we’re using for the automated stator winding means we can get better ‘slot-fill,’ which correlates to an electric drive system with more power and better efficiency,” said Prucha. Next-generation BEV upgrades are en route. “The friction brake system in the front uses half-shafts to connect the wheel motors to the braking system,” Prucha explained. “But that will change, as we’ve already designed and tested an integrated friction brake for the Protean Drive motor to replace the in-board mounting that’s on the F-150 test vehicle today. Protean Electric has several other friction brake solutions that will be available for future applications.”

“Our technology is uniquely designed for a broad range of vehicle applications,” said Bob Purcell, chairman and CEO of Protean. “Our in-wheel motors are unique in that they have the rotor on the outside and each motor’s electronics on the inside. That simplicity of the design creates more power density per motor and much simpler vehicle integration. It’s the closest thing to a bolt-on hybrid system.”

The motor wheels are powerful enough to be the only source of traction drive for a variety of battery electric vehicles. They can also be added to a FWD or RWD car or truck with an internal combustion engine drivetrain, creating a hybrid configuration. In hybrid applications, the technology is designed to be “driver selectable,” meaning driver is able to decide between three operating modes: all electric (city/stop-and-go traffic or low-emissions zones), hybrid (combined constant and slow speeds) or all gas/diesel (constant speeds). They also can provide fully independent torque control, making vehicles safer.

Fig. 1.8 *Protean in-wheel motor for on-road vehicles*

Source Protean Electric

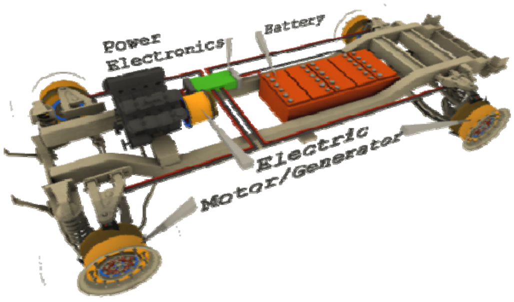
1.4. Motor position

We have seen above that EV motors can be in the wheels, near the wheels ("Electric corner modules"), in the drive train including between wheel pairs or placed centrally for example. EV motors in marine vehicles can be in close proximity to the drive screw, as with AUVs, mimicking in-wheel motors in cars, or placed centrally but other options occur. Basically, in-wheel motors create the option of much more sophisticated multi-wheel traction and steering and certainly they save space. However you never get several motors for the price of one so vehicle costs increase. Indeed, there are also worries about the catastrophic effects of jamming and the challenges to ride and suspension. However, progress is rapid and they are now common on electric bikes and military vehicles and, mainly in trials, in cars.

Fig. 1.9 *Mine resistant ambush protected - All Terrain Vehicle MATV*

Source ARC

Fig. 1.10 *MATV structure*

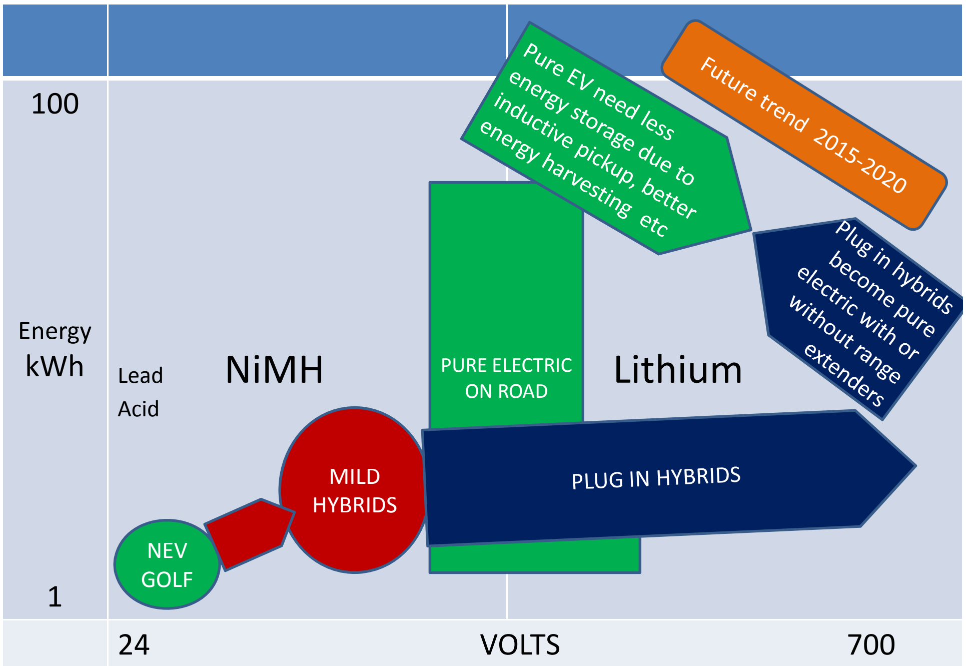


Source ARC

1.5. Trend to higher voltages

Now that high voltage motors are affordable, using high voltage systems in electric vehicles can improve efficiency. However, although many designers are moving to 300-700V, others such as Polaris Industries (All Terrain Vehicles ATV, small industrial vehicles) and KleenSpeed (racing car, sports car, go-kart) see more safety, affordability and adequate performance at tens of volts upwards.

Fig. 1.11 *Traction battery pack nominal energy storage vs battery pack voltage for mild hybrids in red, plug-in hybrids in blue and pure electric cars in green*



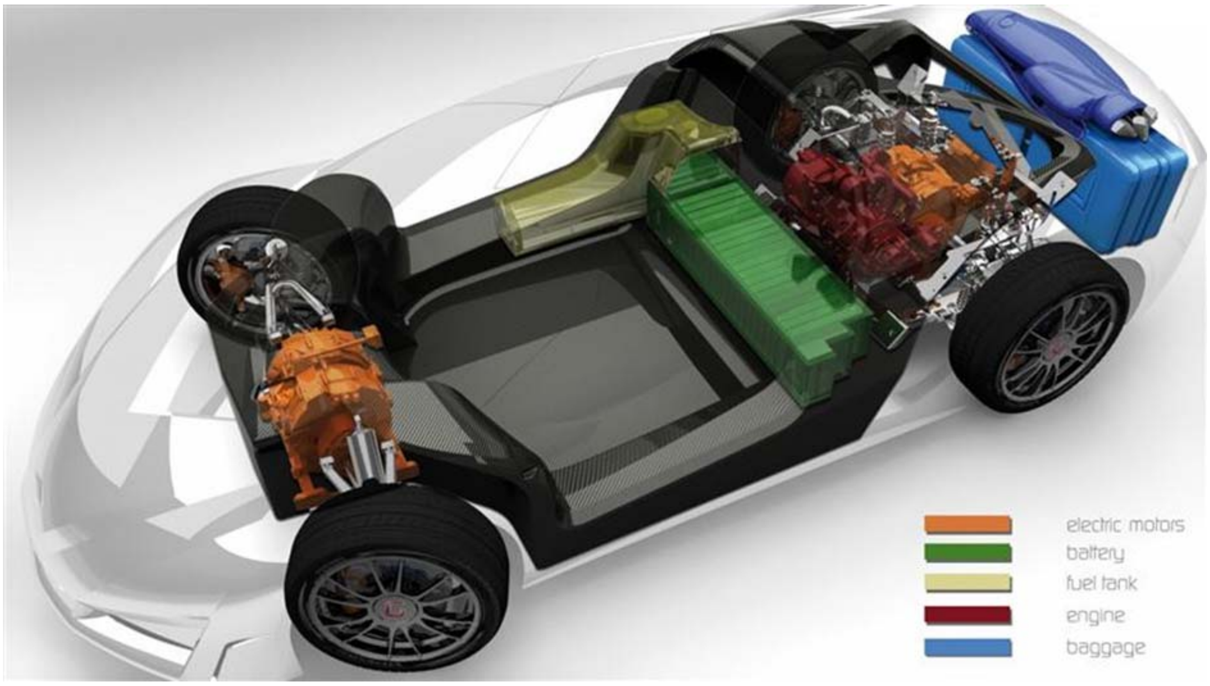
Source IDTechEx

1.6. NEV=Neighbourhood Electric Vehicle which is like a small car but not street legal

The Frazer Nash Namir concept has a 400V system with lithium polymer battery and four motors totalling 276kW. It accelerates from 0 to 200km/h in 10.4 seconds, making it the fastest hybrid car in the world.

Fig. 1.12 *Frazer Nash Namir*

Source Frazer Nash



Source Frazer Nash

1.7. The only comprehensive analysis of the whole EV industry

The IDTechEx electric vehicle team host the world's only events covering all electric vehicles – land, water, air and hybrid as well as pure electric, military and non-military. Less well known is the fact that only IDTechEx analyses the whole market in its unique technical-marketing reports on the subject. The current scope of these is shown below. No one else comes close.

Table 1.6 *The IDTechEx report series on electric vehicles*

Electric Vehicles by Application *All these reports forecast numbers, ex-factory unit value and total market value for ten years*							
		MASTER REPORT Electric Vehicles 2012-2022					
Planned report Industrial and Commercial Electric Vehicles 2012-2022	Electric Buses and Taxis 2011-2021	Electric Vehicles for Military, Police & Security 2011-2021 *including land, sea and air*	Hybrid & Pure Electric Cars 2011-2021	Light Electric Vehicles 2011-2021 *including e-bikes and mobility vehicles for the disabled*	Electric Aircraft 2011-2021 *including manned and unmanned aircraft and airships*	Marine Electric Vehicles 2011-2021 *including surface craft, Autonomous Underwater Vehicles AUVs, private & commercial submarines, sub-aqua scooters*	
Electric Vehicle Technologies *All these reports forecast numbers, ex-factory unit value and total market value for ten years except for the Advanced Energy one*							
Electric Motors for Electric Vehicles 2012-2022	Range Extenders for Electric Vehicles 2011-2021	Electric Vehicle Traction Batteries 2011-2021	Car Traction Batteries – The New Gold Rush 2011-2021	Advanced Energy Storage Technologies – Patent Trends and Company Positioning	Energy Harvesting for Electric Vehicles 2011-2021	Electric Vehicle Charging Infrastructure 2011-2021	Wireless Power Transmission for Consumer Electronics and Electric Vehicles 2012-2022
Geographical							
			Electric Vehicles in East Asia 2011-2021 *with forecasts for China, India, Japan, South Korea, Other East Asia*				

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