The "More Electric Vehicle"

or -The 2nd Electric Revolution?

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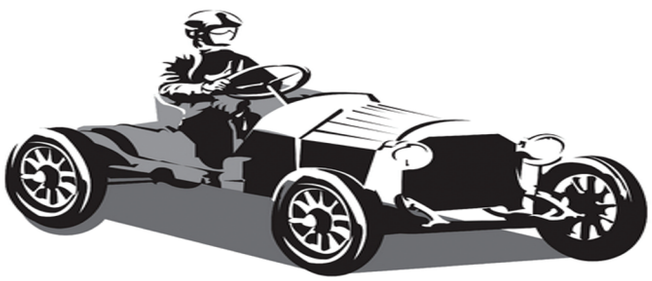
Did you know that way back in the mid 19th century most street and domestic lighting was fueled by kerosene? Arguably, the year 1856 could be considered the birth of the "oil industry". However, in 1878 a certain Mr. Edison invented the first electric light bulb. Unfortunately, there was no infrastructure in place to support such a dotty invention, especially one that needed a plug! Later, this single invention proved to be so popular that it caused a major recession in the oil industry. In only a matter of years, previously non-existent infrastructure quickly sprouted across the land to support the massive public adoption rate. Electricity and electric light bulbs caught the imagination and quickly became ubiquitous, while sales and production of kerosene languished. Was this the 1st electric revolution?

Since those early days, oil made a remarkable comeback via the auto industry, eventually pushing aside all the electric vehicles of the day. Some say due to the invention of the "muffler", and ironically the "electric starter motor". With the loud exhaust noise tamed, coupled with the ability to start the engine from a remote and comfortable position, oil once again became attractive due to its wide availability, relatively simple storage requirements, portability and of course, the ever enduring reason, low cost.



Today, factors such as climate change, rising cost of oil exploration and the threat of "peak oil", local desires for energy independence and the need to scrub the air to reduce pollution –all provide compelling reasons and very fertile conditions for a 2nd electric revolution!

Many layfolk are often surprised to find that vehicle electrification is not at all new, nor indeed are hybrids – as the technology has existed for many decades.

An electric car is not a new idea. While in the employ of Jacob Lohner & Co Ferdinand Porsche developed an electric drive system consisting of hub mounted electric motors. The first production car off the line, using Ferdinand's design, was introduced in 1898 and known as the System Lohner-Porsche. This simple, "carriage-like car" was driven by two electric motors attached directly to the front wheels and powered by batteries. While decades ahead of its time, the System Lohner-Porsche was limited in range and speed by the exorbitant weight of more than 3600 lbs worth of lead batteries. Originally commissioned as a purpose built racer, the car "showed wonderful speed when it was allowed to sprint" but proved to be too heavy as a hill climber.

What is new is the resurgence of interest in recent years due to escalating fuel costs forcing the OEMs to focus on improving fuel economy while providing cleaner emissions and higher efficiency. This has helped drive advancements in electrical performance that will eventually result in the mainstream adoption of more powerful and efficient Alternating Current (AC) Induction machines and Permanent Magnet AC (PMAC) systems. PMAC systems are proving to be very versatile as they have excellent power density, reduced footprint, more torque per dollar, and reduced gearbox requirements; the latter allowing unique and simplified powertrain designs, utilizing direct drive to individual wheels. Current technology already allows for the electrification of many vehicle systems that previously were only considered candidates for hydraulic or mechanical power. Many engineers are realizing, electrification can provide better efficiency, improved design freedom, reduced or no leak points, less complexity, simple or no maintenance, reduced weight and improved power consumption, most resulting in greater fuel efficiency. One wonders why adoption has taken so long to figure things out. The combination of beneficial factors can reduce the overall cost of the vehicle, although it may take a couple of years of ownership to break even due to the higher initial acquisition costs generally involved today. Expect the "electric premium" to disappear over time as high volume production drives costs down.

Inspired by the possibility of creating a vehicle capable of record breaking speed and competing in hill climbing events Ferdinand Porche combined an internal combustion engine with a generator designed to drive the electric hub motors. For added reliability he included a much smaller and lighter battery pack than what was found in the original System-Lohner Porsche. This new design was introduced in 1901 as the Mixte. Capable of speeds up to 35 mph (56 km/h) Porsche created the first petroleum electric hybrid vehicle on record (and possibly the first 4×4 too.)

Some would say that the 2nd electric revolution is already well underway as examples abound from "on" to "off-highway", from Battery Electric Vehicles (BEV) to Plugin Hybrid Electric Vehicles (PHEV), from turf to construction, mining to agriculture and so on. More and more OEMs and engine manufacturers are looking to electrification of ancillary equipment and the introduction of hybrid technologies to address the dual challenges of emissions-reduction and improved fuel economy. Apart from the traditional applications like power windows, seats, wipers, heaters, coolers and such, the new targets for electrification include traction, steering, braking, lifting and lowering. Also, let us not forget those sub systems that should only work when required, thus eliminating parasitic loads such as engine cooling and oil pressure, hydraulic pumps, turbo-

chargers, and exhaust gas treatments.

Those BEV's (Battery Electric Vehicles) that survived throughout the "oil boom" years did so generally because range was not a show stopper, or else gas vehicles were inappropriate (e.g. operating within buildings, or where exhaust fumes and noise were unacceptable). Where dedicated charging infrastructures and procedures could be provided to deal with work routines, the range became a real low priority (e.g. dairy vehicles, golf cars and lift trucks). The traditional technology employed in most BEV's was based on Direct Current (DC) powertrains; however, over the last decade there has been a subtle "technology switch" going on. The lift truck industry has lead the way and has almost completely converted their DC offerings to Alternating Current (AC) –now many non lift-truck OEMs are looking at their success story. Generally, the benefits that can be derived from AC include no maintenance, better vehicle handling, operator satisfaction, higher work output and improved efficiency, allowing more work between charges. In some applications there is the opportunity to reduce battery pack size, and weight. This is quite attractive to the golf and turf industry. All of these benefits are hard to ignore as AC prices become comparable. As a result, expect a multi-industry cascading conversion from DC to AC to continue throughout many industries, but being lead by the likes of the mining, golf, turf, floor care, and ground support equipment. Other industries will follow suit. The advantages of AC systems combined with the ever decreasing cost of the power electronics are likely soon drive switching away from DC.

To maintain this 2nd revolution, many non-electrical engineers will be expected to live outside their comfort zone, and become more electrically minded than they perhaps would like to be. Others will jump at the chance to develop innovative solutions for the future. Modern designers will be looking to replace mechanical, pneumatic and hydraulic systems wherever they can. Some of the simplest "conversions" are those that involve remote actuation, such as blade sharpening, twine binding, deck lifts, hood lifts, quick attach and detachments, plough tilt, and seeder calibration. For simple linear axis', electrical actuation for loads up to 5000 lb. force can now be handled by a single electric actuator. Such actuators are very easy to "design in", "mount" and "wire up," and by default remove leak points, decrease noise, reduce part counts, parasitic loads and system complexity. This makes a compelling value proposition compared to an equivalent hydraulic system. If more force is required it is possible to synchronize multiple actuators to work as one.

One of the greatest issues that will have to be continually faced by Off-Highway vehicle manufacturers is how to deal with ever-tightening emissions standards and rising fuel costs. Governments around the world have plans in place that will continue to drive emissions down through 2015 and beyond, and CO2 will be the next big target. We can expect the regulatory trend toward reducing fuel emissions to continue, further advancing electrification. Most recently, in 2007, the U.S. Supreme Court has authorized the EPA to regulate CO2 emissions.

Notwithstanding the current questions surrounding climate change, pollution and the bio-fuel debate there has been an enormous momentum generated for "change", not only by the green lobby, but by a majority of the developed nations. This is forcing this 2nd electric revolution to dig deeper, far more than simply producing a few more hybrid cars and buses, but all the way through to heavy duty vehicles, as the more intermittent the duty cycle is, the more applicable electrification becomes! Expect to see hybrids in many forms in every vehicle type.

For the "more electric" vehicle to be ubiquitous and the revolution to be complete, the current weak link --the battery (or energy storage) must be addressed. New battery chemistries, coupled with production demand, will drive prices down, while the rising cost of fuel, and the price placed on carbon emissions will increasingly emphasize the better value proposition of electrification in all its forms. We already see a trend towards Plug-in Hybrid Electric Vehicles (PHEV) and, when readily available, advanced energy storage can be coupled with various forms of hybrid logic (e.g. range extender gensets, plug-in chargers). We will witness the infrastructure rapidly gearing up to support it, just like in Mr. Edison's time with his "light bulb".

The challenge right now is to make vehicles go further or work longer on more stored electric energy while continually dialing back fuel consumption. Each year more demands are being placed on the power supply within all vehicles from I-Pods and computers to power-tools. The vehicle of tomorrow will not simply be a mode of transport or a work horse, it will also be a mobile power station that may be able to share its excess energy with an intelligent grid using vehicle-to-grid (V2G) technologies.

The benefits of electrification are really universal. OEMs should be recognized and rewarded for bringing such advances to the market. As we get to the end of the current decade, it will be the norm that big internal combustion engines will be downsized, cleaned up and power-boosted by PMAC motor generators. Hybridization and vehicle electrification in all its forms will be commonplace. Every engine manufacturer and OEM will have product road maps that take us towards the extinction of the internal combustion engine and DC powertrains.

About the Author: Phil Collins holds a degree in Mechanical Engineering from the Army School of Engineering in Bordon, Hants, UK. Mr. Collins has 27 years experience working with off-highway vehicles, including everything from main battle tanks to marine tenders, operation to repair, and everything in between.

For more information about Kollmorgen and its hybrid vehicle solutions, visit www.kollmorgen.com

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