

Construction and Agricultural Machinery as Hybrids

Although construction, agricultural and forest machinery is still dominated by Diesel and hydraulic drives hybridization fairly suggests itself. If the frequently occurring load peaks are buffered electronically cost, consumption as well as the emission of exhaust and noise are reduced considerably.

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Diesel engines of wheel-loaders do heavy work: they generate an enormous force for shovelling, moving, lifting and tilting tons of loads and by the way drive the heavy vehicles. As constant as the engines rev up under peak load, as constant energy is blown out during braking or when lowering the shovel. Almost all construction, agricultural and forest machines, dockside cranes, forklifts, busses and ships mistreat their diesel engines in a staccato of full load and idle speed. The results are an unnecessary amount of noise, wearing and consumption – and emissions the legislators will no longer tolerate this way.



Figure 1: Electrified wheel-loader: serial configuration permits 20,000 litres of fuel to be saved annually at 4000 operating hours.

The limits for particulate filters, nitrogen oxides and hydrocarbons for off-road vehicles have been drastically reduced by the EU since 2001: Was it several grams each of those air pollutants per kWh that were permissible at that time, with the final Tier 4 level in 2014 the values will be reduced to tenths and hundredths of grams. Hence, more efficient drive solutions are required. This is why the Finnish company VISDEDO is pushing off-road electrification with entirely electrical powertrains using WIMA SuperCap Modules as energy storage.

20,000 litres Diesel fuel saved per annum

What difference hybrid drives can make is shown on the example of wheel loaders. Heavy models have diesel engines with a power of around 300 kW which drive both the wheels and the hydraulic system. Due to their dual function they rarely run in their optimum operating map – above all since wheel loaders rather shunt than make distances. But actually diesel engines are too slow in reaction for this purpose. This is totally different with electric motors: Within milliseconds they supply full engine torque from off-condition, load-cycle changes are run more efficiently, and when actuated exactly they enable the traction to be dosed in a way to ensure that the wheels

don't spin even on muddy ground. And all this happens almost noiseless which relieves driver, workers and residents in the same way.

A wheel loader with a diesel engine of only 120 kW instead of 300 kW would be in a position to use these advantages. It runs at almost constant rotation speed and drives a 125 kW generator generating an AC current which is converted to DC current by a 300 A converter for four 75 kW electric motors being installed close to the wheels. Those electric motors drive the wheels and brake regeneratively. They are controlled by a 200 A inverter which at the same time conducts the regained braking energy towards the WIMA SuperCap storage modules exhibiting an energy of one Mega Joule. In this way, advantages in consumption of 25% have thus been achieved in customer projects. As the fuel consumption of heavy construction machinery, harbour cranes or agricultural machinery frequently is 20 litres per hour the saving adds up to 20,000 litres of diesel at 4,000 operating hours with the CO₂ emission being reduced to almost 53 tons per year. Hence, hybridization will pay for itself within two to four years because compared to cars there is one major advantage: as during operation of mobile machinery there are numerous short power peaks it is low-priced capacitors that buffer the power instead of costly batteries. This makes hybrids more affordable and saves the environment as diesel engines in such serial hybrids work almost constantly at the optimum rotation speed which minimizes the formation of harmful substances from the beginning. Also cost of maintenance is reduced since almost maintenance-free electric motors absorb the dynamic loads.

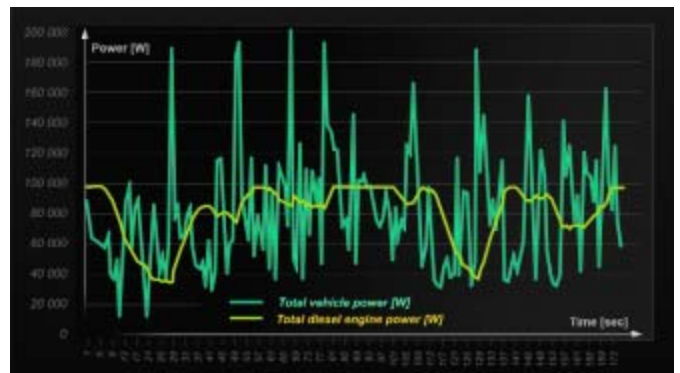


Figure 2: VISDEDO Hybrid with typical construction machine load cycle – up to 50% lower fuel consumption.

Construction needs to be robust

However, hybridization of mobile machinery means high demands to the material because of the enormous power peaks and adverse environmental conditions. Though electric drives are widely mature in

stationary use, it is essential to transfer this state of maturity to the mobile world as well. For this purpose VISEDO develops a modular drive kit using robust components. This hybrid package uses stainless steel circuits for cooling the electric motors and water or a mix of water/glycol for the inverter. An air-cooled construction cannot be considered because of the sooty and dusty ambient conditions, nor special cooling agents as they would not be available in forests, on the field and remote construction sites. The components are encapsulated against dust, dirt and water in accordance with IP-65 and IP-67 standards respectively and submitted to vibration tests with an acceleration of 10 G and bump tests at 50 G. Permanently energized synchronous machines provide efficiency and small component volumes. When operated as generator or traction motor, electric machines work with 96% power efficiency in a range of speed between 400 and 3000 rpm because other than with electric cars mobile machines ask for high torques in a low rpm range and at low speed. There are no agile parts inside the inverter, but high-performance semiconductors as well as miniaturized silver-sintered power electronics. Such power electronics needs to process currents of 250 kW in confined spaces, hence an efficient cooling and temperature-resistant capacitor material is required because the inverters run at temperatures between -40°C and 105°C.



Figure 3: Storage module based on WIMA SuperCaps. Stored energy: up to 2200 kJ



Figure 4: Internal construction of the WIMA SuperCap module with actively balanced single cells.

WIMA / VISEDO Energy Storage Module

As to WIMA SuperCaps, too, the company is focused on robust construction. The product range is consisting of VISEDO CMS (Capacitor Management System) and WIMA Super-Cap Double-Layer Capacitors. The module has been from the start developed to fulfill the requirements in mobile heavy duty applications.

- Modular design allowing the flexibility to fit the product into application needs
- Designed especially for highly cyclical loads typical in heavy mobile work machines and city buses
- Plain water or water/glycol mixture used in cooling
- Wide temperature range -40...+65 °C
- IP69 enclosure class to maximize reliability
- Up to 97% efficiency
- High allowed ambient temperature and long life-time 90 000 h
- Integrated CMS (Capacitor Management System) including control, protection, supervision and communication (CANopen, SAE J-1939)
- User-friendly maintenance and commissioning interface with Visedo PowerUSER™ tool

Parallel or Serial Hybrid

At present the Finnish start-up company cooperates with harbour logistics companies and manufacturers of agricultural, forest and construction machinery as well as of urban busses and ships to realize hybrid constructions. Since serial hybrids are in most cases more expensive a lot of companies decide in favour of the less expensive parallel hybrid construction where the combustor is supplemented merely by an electric engine that operates both as a motor and as a generator.

However, for mobile machines like excavators also hermaphroditic configurations could be considered. Traction and hydraulic load peaks can be smoothened with a parallel hybrid construction, and for pivoting of the vehicle superstructure another self-sustaining electric drive may be used. Also hybridization of stationary working machines could be considered. In wood chippers, shredders or stone crushers electric motors could provide load peaks at full load which would permit the diesel generators to be down-sized considerably. Thus, there is still a tremendous potential for efficiency enhancement slumbering within the off-road sector.

www.wima.de/EN/super-cap_applic_hybrid.htm

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