Emerging onboard technologies are on the cusp of reducing needs for power-switching strategies in overburdened military vehicles and providing electrical power for mobile posts and systems. Anika Torruella explores the possibilities as 'vetronics' rapidly advance.

Weapons technology, cyber threats, and digital capabilities are advancing and multiplying at a profound rate across military forces and platforms, and in many instances are evolving faster than military acquisition programmes have been able to adapt to.

US Army and General Motors plan to evaluate the readiness of fuel-cell propulsion of the ZH2 hydrogen fuel-cell electric vehicle that was unveiled at the October 2016 Association of the United States Army Annual Meeting and Symposium. (General Motors)

Global digitisation has created a fundamental shift in the nature of warfare that perhaps tactical and logistical ground vehicles have been slower to embrace because the growth of interest in digital vehicular electronics (vetronics) has been particularly robust, but open architecture requirements that reduce system and power redundancies, increase interoperability, and standardise components are only relatively recent.

For example, in 2010, as electrical power demands on vehicular systems threatened to outstrip the production ability of belt-driven alternators, the US Army introduced the Vehicle Integration for Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) and Electronic Warfare Interoperability (VICTORY) standard, and the UK Ministry of Defence (MoD) introduced the Generic Vehicle Architecture DEF-STD-23-09. Both standards...
sought to increase interoperability for mechanical parts, standardise component specifications, decrease redundancy of onboard systems, and reduce power loads of combat vehicles.

Increasingly common standards, open architectures, and databus centric designs helped enable vehicular systems to share data and information, and have resulted in the highly complex platforms installed on modern military vehicles.

Vetronics technology has increased in sophistication over the past 15 years, and the mobile platforms have a critical need to generate substantial onboard electrical power to enable various capabilities. These include advanced communications equipment, improvised explosive device (IED) jammers, radars, networked sensor suites, mission recorders, software-defined radios, integrated voice and data software, satellite communications and communications amplifiers, infrared (IR) cameras, shot detection systems, and auxiliary systems such as automatic fire extinguishing systems (AFESs) and advanced steering and cooling equipment.

Gigabit Ethernet interface controllers and quad-core smart displays enable switching and multi-tasking between multiple simultaneously run digital applications; data must be processed in real time and integrated with advanced system diagnostics and health monitoring; and fuel cell improvements have bolstered capabilities to eliminate exhaust, enable quiet operation, or reduce the need to run the engine, while providing exportable power and greatly improved torque performance in off-road environments.

"The electrical power that is built into the architecture of those vehicles has not kept up with all of those technologies," Tom Weaver, senior business development manager for DRS Technologies electronics, told Jane's. DRS is a subsidiary of Finmeccanica SpA. "It becomes like an à la carte menu.... You can put five systems on a vehicle, but the vehicle may only have the architecture load to support three at any one time. So you have to deal with load shedding and 'smart' power management ... but you are picking and choosing what systems you can run at peak time periods."
DRS's OBVP for Navistar's MaxxPro MRAP transformed the vehicle's power train into an electrical powerplant for the Mobile integrated Command Post (MiCP) at NIE 13.2 at White Sands, New Mexico in 2013. (DRS Technologies)

Advanced technology on ground vehicles can provide overmatch against adversaries and enable militaries to fight with a significantly smaller force, but one that is reliant on those advanced technologies, Weaver explained.

"Although those advanced technologies continue to grow today, there are some cutting-edge new ideas targeted at the lethality and survivability focus of ground-maneuuvre forces, but each of those require additional power from the vehicle," he said. This escalation in the use and sophistication of vetronics capabilities requires more processing power to manage high-speed throughput and bandwidth, large-capacity data storage, high-performance video, and high-resolution pixel density, while reducing the size and weight of the power generators.

"And in those instances when the vehicle doesn't generate the power," Weaver said, "what you end up with is the stationary system relying on an either externally mounted generator or a towed-skid generator that is cranked up to provide the additional power required for those systems on the battlefield".

The US Army's Michigan-based Tank Automotive Research, Development and Engineering Center (TARDEC) has also been pursuing advanced propulsion with onboard power (APOP), according to a study of a Stryker vehicle with APOP presented at the National Defense Industrial Association's (NDIA's) Ground Vehicle Systems Engineering and Technology symposium in November 2015.

"In the APOP vehicle one important issue is to make sure that the mobility (or mechanical traction) demand is not compromised under any circumstances," the 2015 Stryker study warned, and added that situations may arise while a heavy electrical load is turned on and the engine is using most of its power for traction when there is not enough surplus power to meet all electrical demands placed on the vehicle. "In this case the only remaining option is to shed some electrical loads based on priority."

Logistical, tactical, and other non-combat military vehicles are often exposed to the same threats as combat vehicles and are also incorporating vital combat-grade vetronics, such as AFESs and other counter-IED systems.

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**Ad-hoc C2**

A mix of disposable and rechargeable batteries "in conjunction with vehicles" can also be used to power communication systems of ad-hoc military outposts, according to research by a Michigan Technological team including Dr Denise Rizzo. The research is to be released at the 2017 SAE World Congress in April. Rizzo was also an author on the 2015 Stryker study.

According to the research, small portable fossil fuel generators aid in establishing combat operations centres and other mission critical ancillary components. As power is depleted during the initial stages of an outpost's deployment, gasoline generators are added. Afterwards, primary
power sources, such as stationary diesel generators, are used to charge energy storage units and provide the outpost with reliable electrical power.

When systems such as the combat operations centre or communication array become fully operational, they are connected to the primary electrical grid. "At this point, the military outpost has a base electrical load, and very limited functionality. As time progresses, additional assets are brought online to increase the outpost's functionality, ultimately resulting in a fully functional installation capable of providing force amplification and support," the research stated.

*The impact of a 7.62 mm rifle round on Raytheon's armour that is combined with integral batteries.* (Raytheon) 1695390

However, combat operations centres responsible for force command and control (C2) are high-value targets, Weaver warned. "C2 capabilities are generally very static," he said. "They are tied to your communications architecture that supports those facilities, and they take a long time to set up and they take a long time to break down and move. What onboard vehicle power does is it gives you the ability to place those critical nodes in survivable manoeuvrable vehicles .... If you do need to move, instead of talking about hours you are talking about minutes to displace your [C2] nodes while maintaining the commander's ability for situational awareness."

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Microgrids

HMMWVs enabled with power exporting capabilities can also be used as a mobile microgrid to supply field hospitals, fuelling stations, or small forward operating bases (FOBs) since they possess "electrical power generation, onboard loads, energy storage, and the ability to interconnect", according to a 2016 Society of Automotive Engineers (SAE) conference paper titled 'Fuel-Optimal Strategies for Vehicle Supported Military Microgrids'. The unique load and silent watch requirements of some military vehicles make them particularly well-suited to augment stationary power grids to increase power resiliency and capability. In addition, vehicle-to-grid applications enable the military to connect multiple vehicles in a peer-to-peer arrangement.

"Being able to treat military vehicles, with their unusual energy storage capabilities, microgrids allow us to frame the control system problem as a network of microgrids," Dr Gordon Parker, one of the authors of the 2016 SAE paper, told Jane's. He added that the vehicle microgrids are different than stationary microgrids but "they have the same fundamental characteristics of energy generation, storage, loads, and connectivity .... Information flows can be a system's 'Achilles heel' due to cyber security vulnerabilities, thus the interest in minimising those requirements."

When interconnected to produce scalable power generation capabilities, military vehicles can support a variety of facilities as a microgrid, and each vehicle could power a subset of an outpost's power needs. However, vehicles must be available to disconnect dynamically to remain integral to on-the-move missions.

"[When] that vehicle is connected to the grid, you can't just drive away that vehicle," Weaver noted. "But because onboard power is adaptable and can be put on a number of vehicles, there doesn't have to be a point of failure ... so I'm not sure that that criticism of tying the vehicle to the node is really that high of a concern."
Weaver explained that a tactical microgrid has the ability to "pull up to a fixed location" like a large camp facility and, using a control device, power C2 and other long-term elements that are stationary.

"The tactical microgrid allows you to create an electrical grid network for the footprint of buildings or tents that each building runs on, making a powerline to a distribution node," Weaver said. He added that the distribution node receives power from a mix of modular generating sources, such as enabled HMMWVs and the portable diesel generators that are typical in small unit outposts and FOBs. Then the distribution node farms out the power and controls the distribution of the electrical energy for the whole grid, smoothing out spikes, and ebbs and flows.

According to the 2017 SAE research, the first step in creating a new outpost is implementing the physical protection and barrier system. "Afterwards, facilities that provide communications, fires, meals, and moral boosts are implemented that steadily increase the electrical load while dynamic events, such as patrols, can cause abrupt changes in the electrical load profile."
It added, "Being able to create a fully functioning outpost within 72 hours is a typical objective where the electrical power generation starts with batteries, transitions to gasoline generators, and is eventually replaced by diesel generators as the outpost matures".

The research also explained that vehicles with exportable onboard vehicular power capabilities are ideal for this electrical power evolution since they are usually already on site and would "reduce the amount of material for outpost creation" and provide a "modular approach to outpost build-up". Such microgrids require scalable power and 'smart' power management software to accommodate the possibly substantial number of assets for the camp or outpost. The management scheme for military ground vehicle-to-grid applications may also require fuel consumption reduction strategies aimed at reducing the risks and costs associated with dependence on supply convoys.

"The US Army is the owner and operator of the world's largest fleet of ground vehicles, and the pursuit of energy efficient vehicle systems that also provide enhanced capability to the military is vital," Rizzo told Jane's. "The use of military vehicles in microgrids does just that. It utilises energy in the most efficient manner and provides enhanced capabilities, such as electrical power for large electrical loads and improved silent watch performance."

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Generic grid architecture with stationary generators, vehicles show the variance of the net power load that must be managed over time. (TARDEC) 1695393

**Silent watch**

Silent watch capabilities are another core objective for vehicles with exportable power capability and substantial battery capacity. "Silent watch is a key concern for militaries," said Weaver. "Advanced vehicles make a lot of noise, diesel engines are not quiet, and during night time ... especially in a desert environment, it's amazing how sound travels."
Weaver said concerns regarding audio and thermal signatures are not new, but they are driving a growing interest for onboard vehicle power innovation. "Silent watch requires batteries," Weaver said. "Batteries are great as long as [they] are charged. So what is the trade off? How many hours of silent watch [do batteries provide]? How many kilowatt hours [of power] do you need [to charge] batteries, and then what are you going to do to recharge those batteries? That's all got to be part of the equation."

The DRS generator controller bus regulator controls the TIG and scales energy output to appropriately meet outpost needs. (DRS Technologies)

He also emphasised that while silent watch is focused on ground-manoeuvre forces, it supports power strategies of air and amphibious forces, and is not restricted to combat vehicles.

"You'll see repeatedly, across the world, that armies rely on standalone-skid or trailered generators to run those systems," said Weaver, adding that trailered and towed systems by their nature restrict manoeuvrability. "And unless you permanently lock that trailer onto a vehicle," he added, "you are restricting it to a stationary mode. All of these are critical factors onboard vehicle power addresses".

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