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The maritime sector tends to avoid changes until it has to, but the ocean going shipping community could not ignore the emissions regulations that came into force on 1st January 2015. This may appear a mundane issue but consider the implications as certain types of vessels are banned from entering ports around the world simply, because of their diesel exhaust emissions. This will increase the cost of world trade as a high percentage of all goods are transported by sea.

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Fuel and Power for Shipping is Changing

The diesel in ships tanks is now getting so light and highly treated that navies are able to run their RHIBs and boats on diesel from the mother vessel. While conventional oil based fuels remain the main fuel option for most in service vessels, Liquid Natural Gas (LNG) is now a proven and available fuel solution for ship propulsion. The commercial opportunities of LNG are now gaining interest for new builds and conversion projects. If LNG does not fit their needs ship operators will consider installing hybrid power systems alongside of their diesel engines. Meanwhile innovative energy solutions may have been ignored in the sub IMO (sub 80 feet) workboat sector if they are only viewed negatively as part of a complicated and costly compliance process.

Workboats Can Learn From Automotive

The race to provide electric power for the highly competitive automotive industry has given battery manufacturers the commercial reason to rapidly improve their technologies. Tesla electric cars can now cover over 200 miles on a single charge. However sales of electric cars are held back by the lack of infrastructure for charging and as many European governments have no spare money for incentives or subsidies the roll out will remain slow.

This is good news for hybrid car producers. Particularly when cars can simply be charged at home overnight and when parked at work during the day. If the journey is longer than the battery range then the gasoline or diesel engine takes over. This will be another factor that accelerates the demand for hybrid diesel / electric vehicles, that switch to battery powered electric drive in town. In the workboat sector there is already a potential charging infrastructure with dockside power and operating ‘in town’ has similarities to ‘in port’.

Diesel / electric systems have been used in large ships and submarines for many years but these are not hybrid systems. The diesel / electric vessel uses its engines to connect directly to an electrical generator. The power in the system is then transferred electrically to the propeller shaft via a motor controller and electric motor. The system may have multiple generators and multiple motors. By strict definition this is not a hybrid as there is no storage of electric energy.

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Hybrid Marine Power and Propulsion Systems

Serial and Parallel Hybrid Power Systems
There are two main types of hybrid system. Firstly a serial hybrid, where the engine in the system only powers a generator and is not mechanically connected to the propeller shaft. Secondly a parallel hybrid, where the engine is mechanically connected along with an electric ‘machine’ that can operate as both a propulsion motor and a generator.

The reduced electric propulsion, generator and battery demands of a parallel system reduce the cost compared to a serial system. Parallel systems are more likely to win initial market acceptance because of a perceived greater reliability, as the ‘trusted’ diesel engine is still connected to the propeller shaft with the electric propulsion adding a redundant system.

Until recently it has not been possible to transfer such systems successfully to smaller craft. A European Union funded project called HYMAR (High efficiency hybrid drive trains for small and medium sized marine craft) set out to develop an optimised hybrid system. The conclusion at the end of stage one was that the initial focus on ‘serial hybrid’ systems had been misplaced, and that the project’s objectives would be better met by ‘parallel hybrid’ systems. As stage two HYMAR developed a parallel hybrid system that has been installed, tested and validated on marine craft. HYMAR has also built a comprehensive energy management module and graphical user interface to control the energy flows of an entire craft. The optimised hybrid system developed during the project offers three major advantages - no detectable emissions, no discernible noise and a substantial reduction in fuel consumption.

Next Generation Cells and Batteries
Battery powered electric motors have been available on small craft for many years. But until recently electric outboard motors had been mainly under 10hp for small fishing boats, tenders and kayaks. The main obstacles to overcome before scaling up had been battery technology and the high initial cost of procurement. Deep Blue is an electric drive system that has been industrially developed and manufactured by the German company Torqeedo, using high-tech components. The system is available as 40hp and 80hp inboard or outboard versions.

The next generation of cells and batteries are key technology developments that are making marine hybrid systems potentially viable. Battery chemistry such as Lithium-ion offer impressive power solutions and the business case is starting to fit for commercial operators. Since there is no single system that fits every application it is important to work with manufacturers that have flexibility in cell manufacturing and offer scalable solutions. New factories with fully automated processes ensure consistently high quality cells and quality control of the entire battery management system.

Michigan based XALT Energy offer several variants of High Energy, High Power, and Ultra Hi-Power cells. Robert Young, Technical Lead for Marine Applications at XALT Energy, said, ‘our team of engineers have worked to the highest standards developing electric and hybrid energy solutions for the US and global automotive sector. XALT Energy not only has the necessary knowledge, but also the experience of taking high voltage battery projects from concept through production into the finished system.’
Hybrid Marine Power and Propulsion Systems

Integrating High Voltage Systems on Boats

Battery banks require space and as they not usually replacing another component this can be an issue for smaller craft. Naval architects require additional weight to be low and central for most designs of small craft. Once the onboard space and footprint are allocated battery designers and engineers need to consider issues specific to marine applications. These include shock and vibration when a boat is underway plus the challenges of installing high voltage systems in enclosed spaces. Although modern batteries are expected to have a long life, they need to be carefully positioned to enable access for inspection. Integration needs to consider onboard safety plans and risk management regarding crews, passengers and critical systems.

Cost / Benefit implications will start with the initial purchase of the system then work out payback period based on the life cycle of the vessel and life cycle of the hybrid power system. Once a system is defined projections and audits can be based on engine management data linked to work cycles. Hybrid systems are infinitely scalable which enables owners to specify what they are trying to achieve over a period of time or an entire fleet.

Opportunities for Retrofit and New Builds

When studying work cycles of vessels it is relatively straightforward to make a decision for new builds on whether to go for all electric or a diesel / electric hybrid system. For example a ferry operating over a short route with a long stopover each end could offer the perfect work cycle for ‘electric only’ with a land based charging system. Other issues, such as the cost of downtime and structural alterations affect viability calculations for retrofit of in-service craft.

Certain maritime sectors are potentially well suited to ‘hybrid’ diesel / electric systems. These include wind farm service vessels (WFSV) and pilot boats that have relatively consistent duty cycles, often running seven days a week to drop off or collect technicians and pilots.

Hybrid Systems and ‘The Hour Of Power’

Indentifying the viability of hybrid diesel / electric power for offshore wind farm support vessels is an interesting project that links green energy onboard with renewable energy from the environment. Hooking up to offshore wind farm turbines may even provide charging options.

The first objective is to focus on the sub IMO (sub 80 feet) workboat, pilot boat and patrol craft sectors to investigate the engineering and systems integration required to bring together viable and sustainable solutions. With vessel life cycles of over 20 years, naval architects and builders of new craft will offer designs that have space and access routes to enable retrofit of hybrid installations. Speed limits in harbours at beginning and end of daily transits may mean that ‘The Hour Of Power’ is all that is required for the electric part of the cycle.

BAE Systems is a provider of hybrid propulsion systems with technical experience in hybrid technology for land based applications. BAE Systems aims to partner with manufacturers of marine diesel engines to provide complete propulsion and auxiliary power systems to increase the operating efficiency and performance of a vessel, while reducing fuel costs and emissions.

ZF Marine offers a range of hybrid-ready transmissions and propulsion for larger fast craft applications. The design is based on a unique Power Take In (PTI) configuration, allowing highest flexibility for customizing installations. These transmissions can be integrated into hybrid propulsion systems for all types of fast craft, from coast guard vessels to fast offshore supply vessels.

Siemens have extensive experience of hybrid and electric technology for various modes of transport. Siemens offer both series and parallel hybrid systems for the commercial marine market.

65 metre Offshore Supply Vessel with hybrid propulsion system for the Italian Coastguard. Image credit Siemens AG
Hybrid Marine Power and Propulsion Systems

Power and propulsion systems that are designed and built for professional or commercial operations need to run hard, often for long hours in adverse sea conditions. Users must be able to rely on these systems at all times. In certain situations failure is not an option – the engineering must not break. Professional boat operators around the world have learned that power and performance are relevant, but reliability and durability are important factors for all types of engine and propulsion.

Effective Integration & Global Partnerships
The Hybrid community will need to engage with diesel engine manufacturers. New high tech companies entering the market will want to utilise the existing relationships that diesel engine OEMs have with end-users, boat builders and standards agencies. The importance of an international service, spares and support network will add confidence to procurement and life cycle maintenance decisions.

If the marine industry wants to move forward quickly it will have to build teaming agreements and partnerships that bring together technologies.

Hybrid marine will not tolerate inferior parts. All components will need to be built to the highest industry standards and designed to integrate globally across multiple platforms.

Hybrid Power Technicians in the Shipyard
There are clear opportunities related to problem and solution however the integration of products will be crucial. There will be a new career in shipyards for ‘Hybrid System Integrators’. These will be individuals and teams that have a holistic approach to engineering and many will need to be qualified high voltage technicians. When integrating hybrid systems a shipyard will need to identify which competencies are required. To warranty the system it will need to define who signs off the installation and the components on handover. Manufacturer’s liability is a commercial reality that can be hidden behind factory recalls on land, but at sea a single point of failure will reflect on all OEMs in the hybrid power ‘system’.

Implications of Legislation and Standards
Various legislation and standards have implications for end-user organisations, boat builders and equipment manufacturers. As cells, batteries, power generation and storage evolve it is important to address misconceptions and myths to enable progress. For example Lithium Ion has been part of our lives in non-marine sectors for many years as the battery power behind electric cars, city busses, smart phones, tablets, laptops and cameras. Besides how to present performance metrics it will be essential to identify whether current standards from land based applications are valid. An environment with electricity, water and damp enclosed spaces requires specific testing and sea trial standards. A new ISO standard for high voltage DC propulsion systems and comprehensive energy management in maritime environments will be relevant.

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Maritime Aquarium at Norwalk’s vessel ‘Spirit of the Sound’ equipped with BAE Systems HybriGen technology and Li-ion batteries for energy storage. Copyright: BAE Systems.

The Explorer’ is a SWASH (Small Waterplane Area Single Hull) pilot boat with a hybrid drive system from Siemens. Copyright: Abeking & Rasmussen AG.