An Advanced "Green" Propulsion Configuration

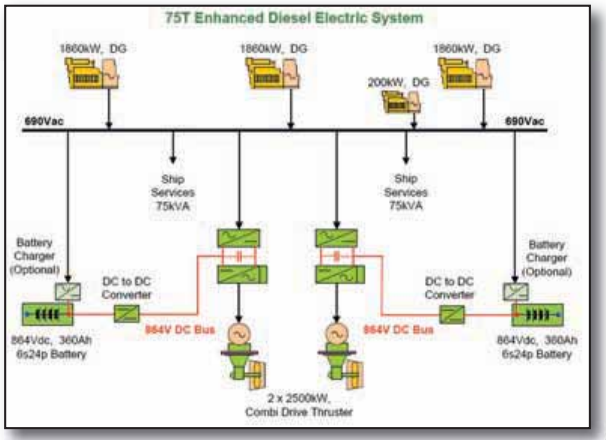
GPM Provides Greater MPG

By Dan Koch and Inga Scholz, Guido Perla Associates

Although shipping is still the eco-friendliest mode of transportation, green issues and concerns about the impact on the environment by maritime operations and municipalities are becoming more important for operators and vessel designers globally.

Increasingly stricter regulations, such as Tier 2 and Tier 3 engine emission requirements, are influencing naval architects, operators and suppliers worldwide to develop and employ vessels capable of operating at reduced emission levels and with greater fuel economy.

While some maritime sectors, such as Offshore, are already operating more fuel-efficient vessels at improved emission levels, made possible in part by now widely accepted diesel-electric (DE) and series diesel mechanical/electrical (SDME) propulsion configurations, other sectors have just recently considered veering towards environmentally friendlier solutions. One such sector is the tug market. Consider harbor tugs, which exhibit less than ideal operational profiles due to long periods of idling at inefficient engine loads, combined with the infrequent need to operate at full power. Such tugs operate in harbors usually relatively close to inhabited areas, whereby the emissions, most often characterized by the "black puff of smoke", which occurs mostly during acceleration or rapid load changing, have an imminent impact on the surrounding regions. Ocean towing vessels, on the other hand, operate more often at constant speed and therefore possess a better fit between the conventional propulsion system characteristics and the operational profile. Escort tugs have yet another operational profile. The specific region and navigable waters in which these vessels operate compound the different operating profiles. Minimizing the effects of tug operations on the environment, regardless of the tug type, has been a target for concerned operators and designers for quite some time. Therefore, reducing emissions and improving fuel efficiency have become ongoing objectives of utmost importance for many environmentally conscious companies in the marine industry.



"Image Courtesy of L-3 Communications)

Naval Architect Guido Perla & Associates, Inc. (GPA) along with L-3 Marine and Power Systems (L-3) have developed an advanced concept for a propulsion system not only for tugs but applicable to offshore vessels, and others as well, combining both proven and state-of-the-art technologies into a propulsion package which is greater than the sum of its parts.

Coupled with the desire for decreased maintenance cost as equipment can be utilized closer to ideal performance levels, as well as enhanced workplace health and comfort/noise conditions, the measures taken towards green operations are beginning to assume a definitive shape.

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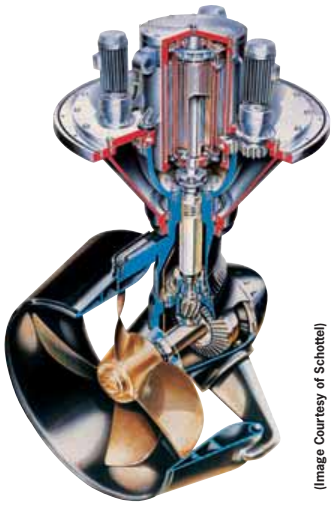


(Image Courtesy of Schottel)

The motor in the SCHOTTEL Combi Drive is integrated vertically into the support tube of the Rudderpropeller. Neither an above-water gearbox nor a shaft line is required, making the system extremely compact and easy for the shipyard to install in the vessel with very low space requirements.

Following the development of this concept, GPA and L-3 were joined by an operator in the tug world, to further develop this design with the ultimate goal of introducing it to the tug market in the near future. Dedicated to embed the green mindset into the company's operations, the operator has been involved in the development of green vessels for a period of time, investigating modifications to improve emission levels and fuel economy and reduce environmental impact of operations. With the operator's close support to GPA and L-3, and therefore the benefit of direct input from a experienced tug operator with a keen interest in taking steps towards an environmentally friendlier operational future, the EDE tug project evolved into the Advanced GPA 335E Enviro Tug.

The Series Diesel-Mechanical/ Electrical (SDME) Propulsion Arrangement on Harbor Tugs

GPA and L-3 initiated this concept by examining existing and new propulsion technologies and configurations used on harbor/escort tugs and while advantages are apparent with new technologies, certain deficiencies still existed. For example, a Series Diesel-Mechanical/Electrical (SDME) propulsion arrangement, which is also similar to systems used on some large Anchor Handlers, is a reasonable option

for vessels spending a significant amount of their operations at full power and for vessels with a very specific and constant operational profile. The main reason for this is that a large percentage of the total power, ideally above 60-70%, is produced and delivered mechanically, which generally has lower losses, approximately 3-5%, than an electric propulsion system, which incurs about 8-10% losses.

A harbor/escort tug though only spends a very small amount of its time at full power, even during ship assist maneuvers, whereby the application of thrust is quite variable. The time between ship assist jobs is also quite variable. Therefore, such an SDME propulsion arrangement on a harbor tug exhibits some technical and operational deficiencies if the main target of the arrangement is to address the increasing environmental problem of emissions.

Considering this, the batteries in such a configuration primarily serve as a "band-aid" for the "puff" of black smoke that occurs due to the lag in winding up the turbo upon rapidly increasing throttle commands. The batteries/generators do offer additional operating modes that can reduce fuel consumption during stand-by or reduced load operations. However, since these modes require selection by the Captain, they are likely only used when it is certain that full power will not be needed. Therefore, for escort, ship-assist, and possibly even transit in a busy harbor, the SDME with batteries (SDMEB) system is not operating considerably different than a conventional tug, except for preventing the "puff" of black smoke, because the main engines are engaged.

Taking Advantage of Diesel-Electric Systems: The Enhanced Diesel-Electric Propulsion System (EDE)

In offshore vessels, the advantages of Diesel-Electric (DE) propulsion have been well proven and have been at the heart of GPA designs for many years. These vessels benefit from a power management system to distribute power from a common generation plant for propulsion, cargo pumps, deck equipment, and other electric consumers as these loads vary during operations. Similar to the human factor limitation of the SDMEB tug, whereby the selection of operating modes depends on the comfort level of the Captain, DE systems in offshore vessels often require "spinning reserves" to satisfy the redundancy requirements for Dynamic Positioning. Accordingly, DE offshore vessels commonly have diesel generators operating at partial load during DP in order to have the required redundancy. Though much improved over the old diesel-mechanical days, it is far from optimum with regards to fuel-consumption, which until recently has not been much of a focus since the operator generally receives their fuel from the customer.

GPA believes that the solution for tugs and for offshore vessels is very similar, even though the operational profiles are vastly different. The Enhanced Diesel-Electric (EDE) concept utilizes currently available technology and yet retains the ability to incorporate evolving technology as it becomes commercially available.

Some of the key factors that GPA believes to be important with any Green Vessel design are:

- Significant reduction of fuel consumption, as well as NOx, SOx and CO emissions
- Prevention of black smoke
- Independent of operational profile
- Seamless operations (does not require mode selection)

- Diesel engine operations in the most efficient load range (50 – 90%)
- Reduced lifecycle cost
- Use of currently available technology
- Flexible and expandable (possible incorporation of future technology, such as solar, wind or current power).
- Improvement of workplace health and comfort/noise conditions.

In general terms, the Enhanced Diesel-Electric propulsion system (EDE) utilizes:

- High-speed diesel generators
- Combi-drive thrusters with fixed pitch propellers and high efficiency motor (Figure 1.)
- Variable frequency drives
- High efficiency energy storage (Currently batteries, but could incorporate a combination of super capacitors, batteries, flywheels or fuel cell technology)

For many operators, the use of medium-speed propulsion engines has long been desired for mechanical systems due to the lower life cycle costs and perceived durability of these engines. However, high-speed diesel generators are widely accepted today and offer lower weight, less required space, and lower cost for electric propulsion systems. The upper gearbox of a conventional Z-drive contributes about 2.5 % to the mechanical losses, thus a Combi-Drive eliminates this and helps offset the inherent losses of converting the electrical power, along with the elimination of the shaft. Therefore on the surface, an ASD tug with an electric propulsion system would exhibit, at best, 2.5% less efficiency in the total power conversion/transmission. Depending on the operational profile, this may or may not be offset by the added flexibility and through power management. A concept to overcome this and assure greater fuel economy and fewer emissions regardless of operational profile was therefore needed and resulted in the development of the Green Power Module (GPM) and EDE concept by GPA and L3.

Energy Storage is Critical to Success

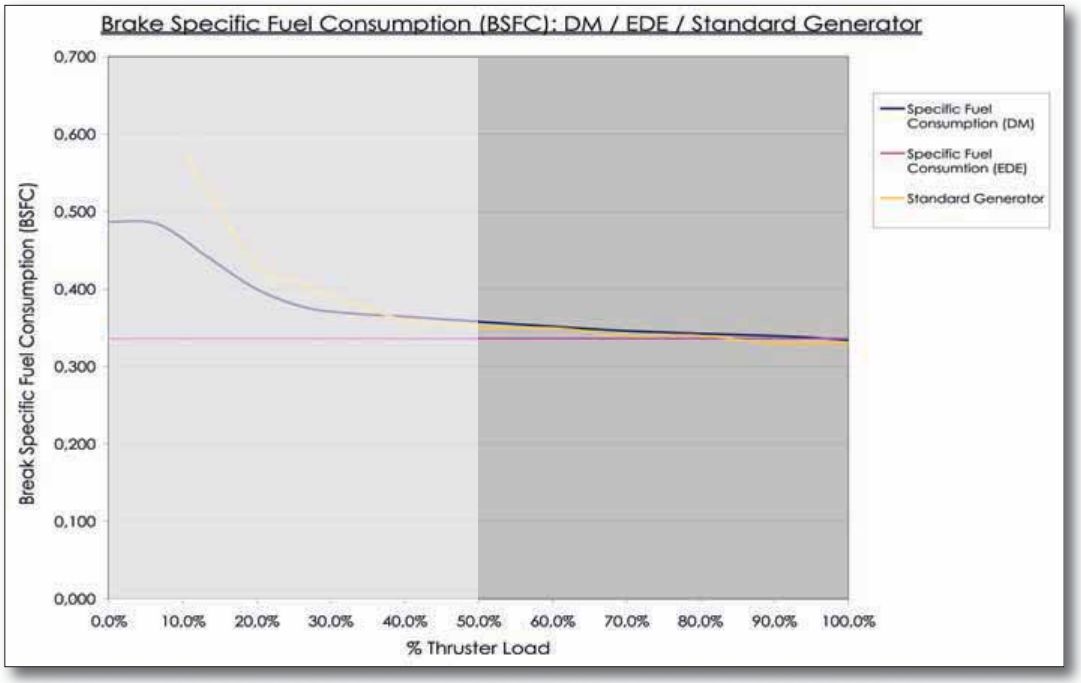
The argument against DE systems for tugs has been that the specific fuel consumption of a diesel generator operating at low load is significantly higher than a variable speed propulsion engine operating at low load and low rpm.

This is where the energy storage becomes so critical to this concept. The batteries act as a buffer to the power demand and allow for the system to operate essentially as a "constant load - constant speed" system while also providing the same buffering capacity to prevent black smoke during rapid throttle commands as with the SDME system (Figure 2).

Figure 2.

For the GPA 335E ASD tug recently developed the concept consists of three diesel generators with a nominal power of 1840 kW each, two battery packs with a capacity of 324 Ah each, two electric motors and two Azimuthing thrusters. The generators are connected to the power grid via an AC bus. Through this AC bus, the generators can supply power to the two electric motors, the batteries or ship services. The power supplied to the batteries is used to charge the battery packs. This is done through a DC-DC converter connected to the DC link of the propulsion motor drives. The batteries can, also supply the power to the electric motors, or the power needed for ship services. The design thus has the possibility of delivering power to the thrusters in three ways but does not require any mode selection and is seamless to the operator:

1. With the diesel generator sets
2. With the battery packs
3. Any combination of both generator



sets and battery packs.

Though the batteries are sized to provide full bollard pull for the period of time necessary to bring the diesel-generators on-line, they are significantly smaller than those in previous hybrid designs because they are only used as a buffer for the diesel-generators in order to get them started and online as a response to a rapid increase in power demand, and to provide supplementary power (or load) to ensure that the generators are at optimum performance of 50-90%. They also offer a significantly longer life than the lead-acid batteries commonly used

The batteries are also able to store energy received from a shore connection. If the vessel berths and connects to the shore connection with depleted batteries after a job and leaves the berth fully charged, the re-charged energy will be equivalent to the fuel saved and emissions not emitted.

In general, the batteries in the EDE concept can be considered as a filter on the specific fuel consumption curve of the diesel engine, which is always operating at optimum load, and constant speed, therefore making its specific fuel consumption and emissions significantly better than a variable speed propulsion engine for light thruster loads (Figure 3).

The battery type selected also does not contain heavy metals like Cadmium and Mercury, which are very toxic and can cause substantial pollution when land filled, which has been the main reason for the European Union for instance to prohibit the use of Cadmium portable batteries or accumulators, and has been an important consideration for this "green" concept.

Since a harbor/escort tug spends most of its time idling or at a low thruster loads, a standard Diesel Mechanical system (DM) clearly show increased fuel consumption at inefficient loads below 50%. The EDE system on the other hand exhibits a constant, efficient fuel consumption throughout operations, independent from the thruster load, by allowing the generators to operate only in their most efficient range. The EDE system therefore operates at a specific fuel consumption level, which a conventional system only achieves at higher thruster loads.

In addition to the reduced fuel consumption, emissions and running hours, this propulsion concept benefits from several other advantages.

1. The vessel is able to provide maximum bollard pull for as long as the operational need dictates.

2. There is no need for the captain to select power management settings while operating the tug.

3. Because of the inherent high power generation per hour, the running hours of the engines will be greatly reduced, reducing maintenance costs.

4. While operating on batteries or in standby mode, the airborne noise emitted by the tug is greatly reduced and the tug will emit very few to no exhaust emissions.

5. The lack of a direct drive shaft enables design flexibility. For instance, introducing noise and vibration reducing measures is expected to be easier in comparison with conventional designs.

6. Energy needed for hotel loads can also be generated within the high efficiency range.

There are of course other lifecycle cost benefits that are still under development, however, it can be anticipated that one-less gear set in the thruster, elimination of shafts and bearings, fewer operating hours on the engines coupled with the fact that they are constant speed machines, optimally loaded, will result in lower operating costs.

Resulting Fuel Consumption and Emissions

The reductions in fuel consumption and emissions that can be achieved by using the EDE concept are dependent on the considered operational profile, though it is not designed for a specific profile and will enhance any operational profile. For typical tug operations in harbor or terminal work, the EDE concept realizes significant fuel and emission savings in comparison to conventional diesel-mechanical propulsion. This is due to the engines being operated in their optimal load range (even if little power is required) or even shut down when no propulsion power is required.

For a typical operational profile of a harbor tug, it is expected that the EDE system offers fuel savings of approximately 15%. Related approximate emission reductions are as high as 15% for CO2, 45% for NOx and 16% for SO2. The reduction in local exhaust gasses emitted by the tugboat and fuel consumed can be further reduced by the use of power from shore installations stored on the ship propulsion batteries which could amount to fuel savings of 40% or more.

Response to Power Demands

The beauty of the EDE concept is that it does not require a conscious decision to operate efficiently. The system automatically and seamlessly responds to the required power demands, keeping the generators optimally loaded, eliminating any visible signs of pollution, while maximizing fuel efficiency and minimizing CO2, SOx and NOx emissions. As stated earlier, the problem with the Captain having to choose manually between operating the tug in "green" mode, or having full thrust capabilities immediately available, is that if there is any doubt with regards to the required maneuverability or operational safety - he will most likely operate with all engines engaged, thereby negating the affect of the "green" measures.

Committed to continually reducing the impact on the environment with its designs, Guido Perla & Associates, Inc. believes its Enhanced Diesel Electric Concept, utilized on the GPA 335E Enviro Tug, to be a realistic approach to addressing the ever-growing issue of emissions, optimizing the use of existing technology while being flexible to incorporate future technology. In addition to the tug market, GPA foresees opportunities to apply the concept to Offshore, Ferries and other vessel types.