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INLAND TOWBOATS AND DIESEL ELECTRIC PROPULSION

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Diesel electric propulsion is not a new concept. However, like azimuthing drives, its application to the inland marine market is lagging other areas of the marine industry. Diesel electric has gained traction in industries where fuel economy and redundancy of propulsion sytems for safety is paramount. In particular, vessels like passenger ferries and offshore supply vessels have enjoyed the benefits of the diesel electric systems. The inland towboat industry shares many of these concerns, and would benefit from the consideration of diesel electric technology as part of a comprehensive engineering design process.

In early 2017, The Shearer Group, Inc. (TSGI) embarked with the marine division at ABB to study applying diesel electric technology to the inland marine industry. TSGI originally researched diesel electric propulsion for towboats around 2007, but at that time the technology and price did not make it a feasible option for the market. However, in the last few years some fundamental industry changes have shifted the equation making diesel electric a viable option when planning for a new towboat.

What is Diesel Electric Propulsion?

Simply put, diesel electric propulsion is a concept that uses an electrical power plant consisting of multiple power generators that develop electrical power to the propulsion plant via the use of electric motors.

The electrical propulsion system consists of generators, an electric distribution system, variable frequency drives, electric propulsion motors, and a control system.

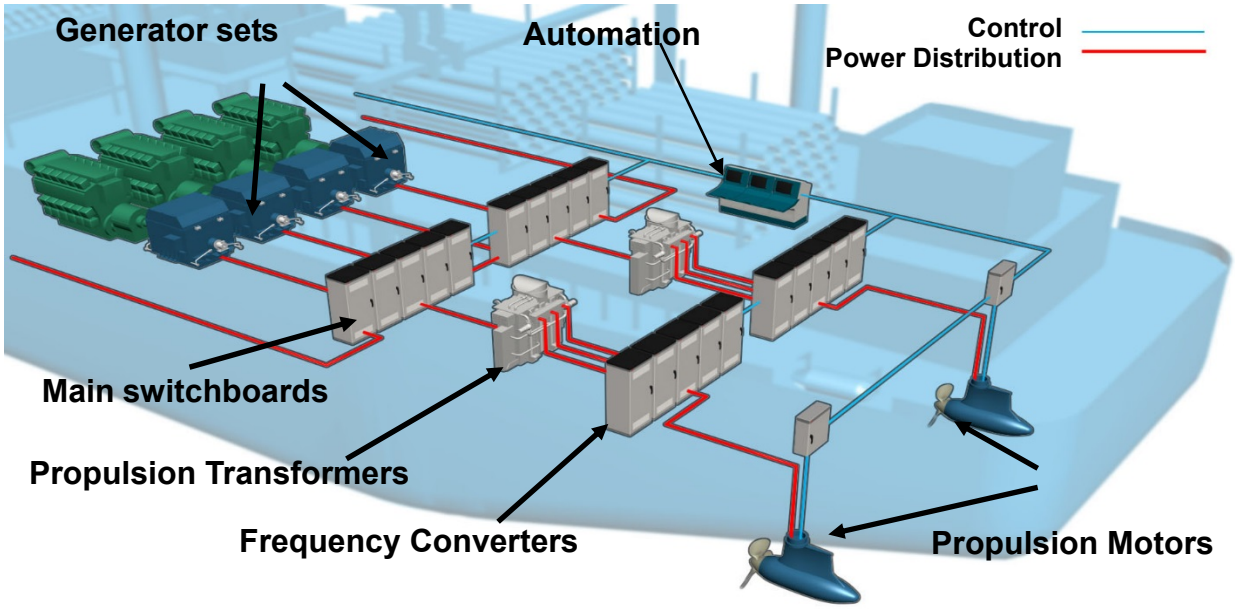

Figure 1: Electric Propulsion

Mechanical diesel driven systems provide superior efficiency in a very narrow range of operations, typically above 60% MCR. As such, it is important to determine the total operational cycle of the engines over a long course of time. Diesel electric improves efficiency of a vessel's propulsion system by broadening the range of optimal operations and providing more overall efficiency in ranges outside the optimal range of a mechanical drive system.

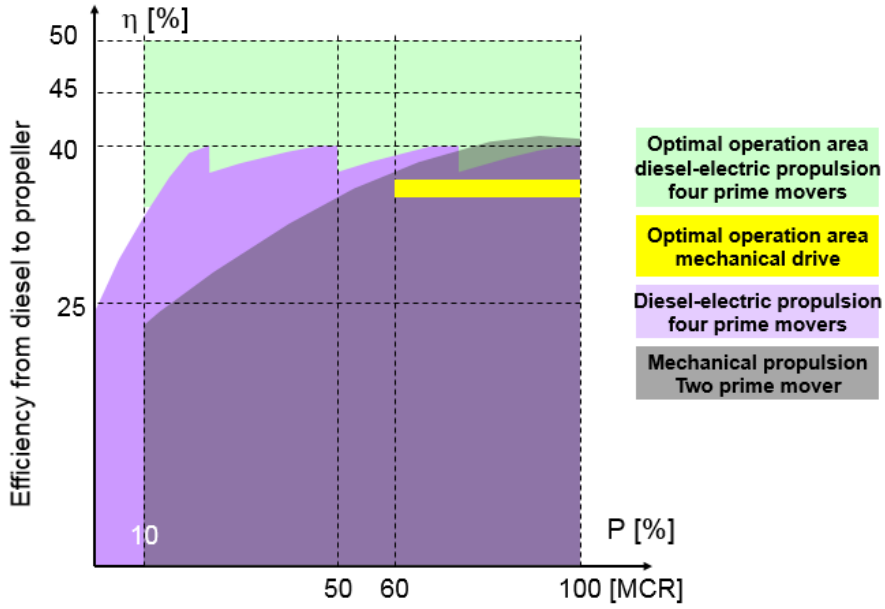

Figure 2 Areas of Efficiency Gains

Under the umbrella of diesel electric propulsion, there are several variants that exist on the market today:

Hybrid (PTO/PTI)

Hybrid systems make use of a mechanical shaft line with a power take off and power take in (PTO/PTI), combined with an electrical generation system. This sytem combines the benefit of direct drive propulsion through a gear box with the flexibility of a 'power boost' from the ship's electrical system, but also allows for the main engines to run more efficiently by providing electrical power to the ship when the power is not needed for propulsion purposes. When more power is needed, the generators act as motors supplying additional power to the shafts via the PTO/PTI. During lower power operation, the main engines can be clutched out and the vessel can operate on the electrical motor alone, or the main engines can supply propulsion power and also power the PTO/PTI for supply of electrical power for auxilliary loads.

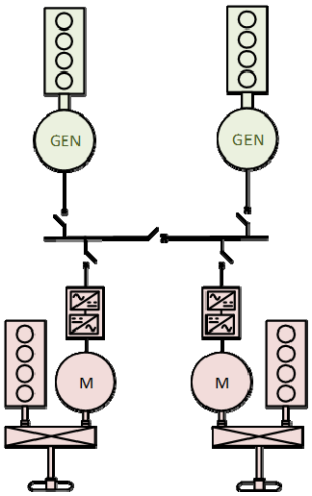

Figure 3: HYBRID (PTO/PTI)

A/C System

The A/C diesel electric system is the most traditional and common diesel electric system on the water today. It consists of an electric power plant with several generators providing power for all of the loads on the vessel; propulsion, auxilliary, and hotel. Power from the switchboard is provided to the propulsion motors via variable frequency drives in order to allow the motors to operate at virtually any shaft RPM.

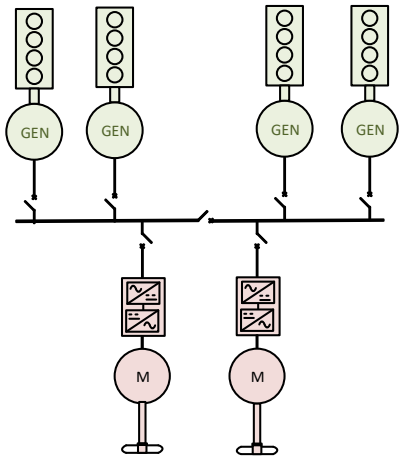

Figure 4 A/C System

D/C System

The D/C diesel electric system is very similar to the A/C system but provides some improvements in certain areas. The AC current from the generator is rectified to DC at the generator and distributed directly through the switchboards. The DC current is then inverted back as necessary to provide AC power to the propulsion and hotel loads. Direct Current systems are smaller and lighter in general, with fewer parts inside the switchboards. DC based propulsion systems provide the most benefit when combined with some type of energy storage where the DC grid can allow the batteries to provide instant power response to the ship's electrical system.

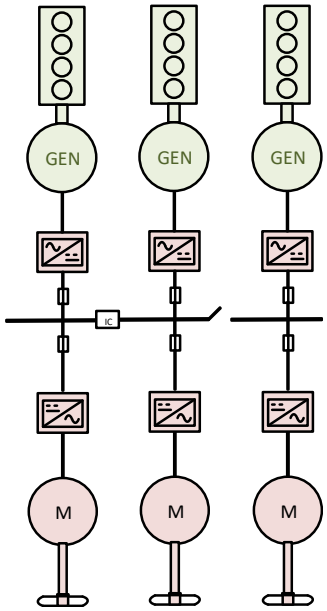

Figure 5 D/C System

Diesel Electric With Energy Storage

When diesel electric systems are combined with energy storage, the benefits of diesel electric systems continue to improve. For typical marine application, the use of Lithium Ion batteries (Li-ion) can help add spinning reserve, peak shaving, and zero emission operations to increase the overall efficiency of the vessels.

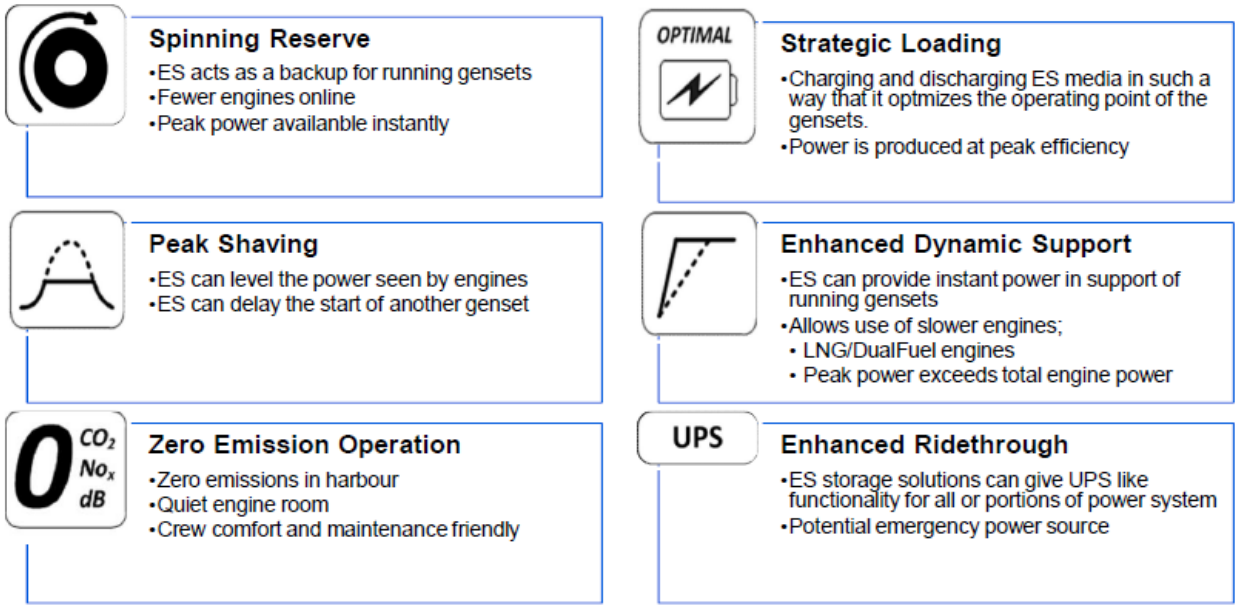

Figure 6 Energy Storage Benefits

How Diesel Electric Fits for the Inland Market

To date, most of the focus on diesel electric has bypassed the inland towboat market. However, TSGI has been working with engineers from ABB to develop and fine tune the diesel electric towboat design concept. The impetis for the design effort is the typical towboat's operational profile. When we asked owners how they operate their vessels, most believe they are between 80%-100% load nearly 100% of the time. In reality we found that actual engine data from vessels operating on the rivers was quite different.

Instead of operating at over 80% loads the majority of the time (as previously thought), we found that the operational profile of the vessels we investigated spent far less time above 80% load than originally thought.. What we found from a number of operators on various parts of the inland rivers is that the actual towboat spends most of the time below 50% total power, with short peaks above 80%. This opens much opportunity for diesel electric to provide positive impacts on the operational costs associated with running a towboat on the inland rivers.

Vessel operation profiles such as those shown below are very important in determing the suitability of a diesel electric system for a particular vessel. Both of the sample profiles below represent real operational data over the course of 365 days of operation for different vessels.

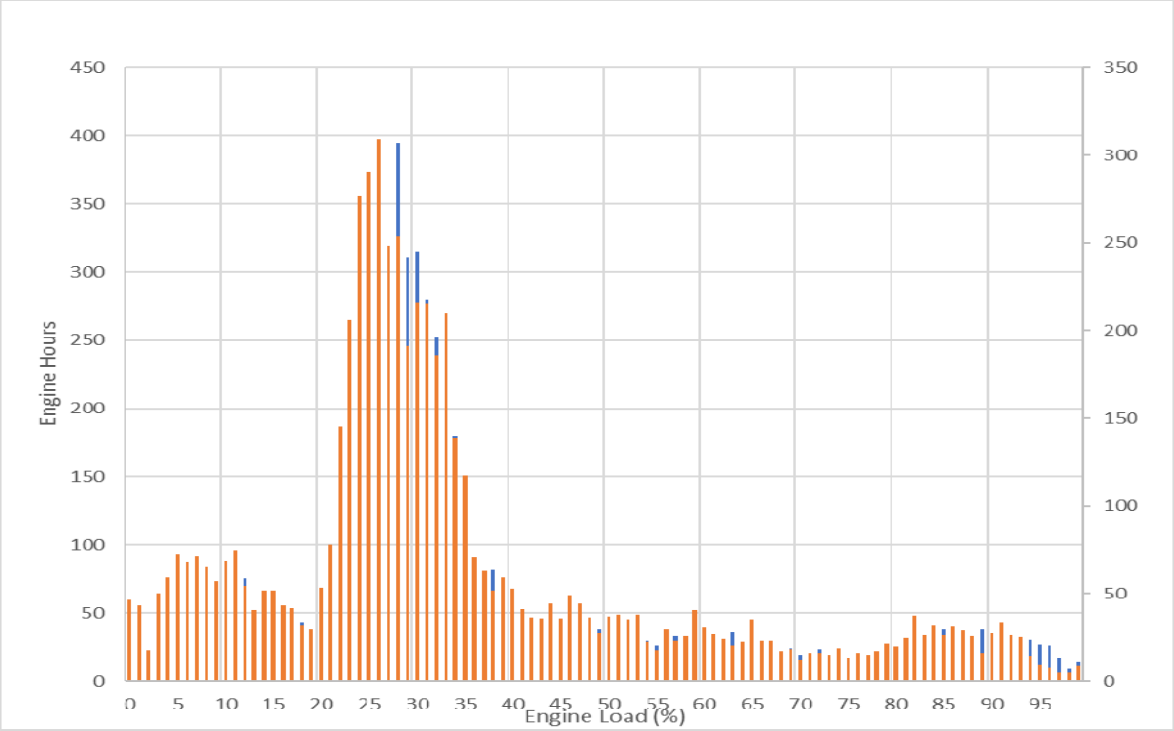

Figure 7 Lower Mississippi Profile #1

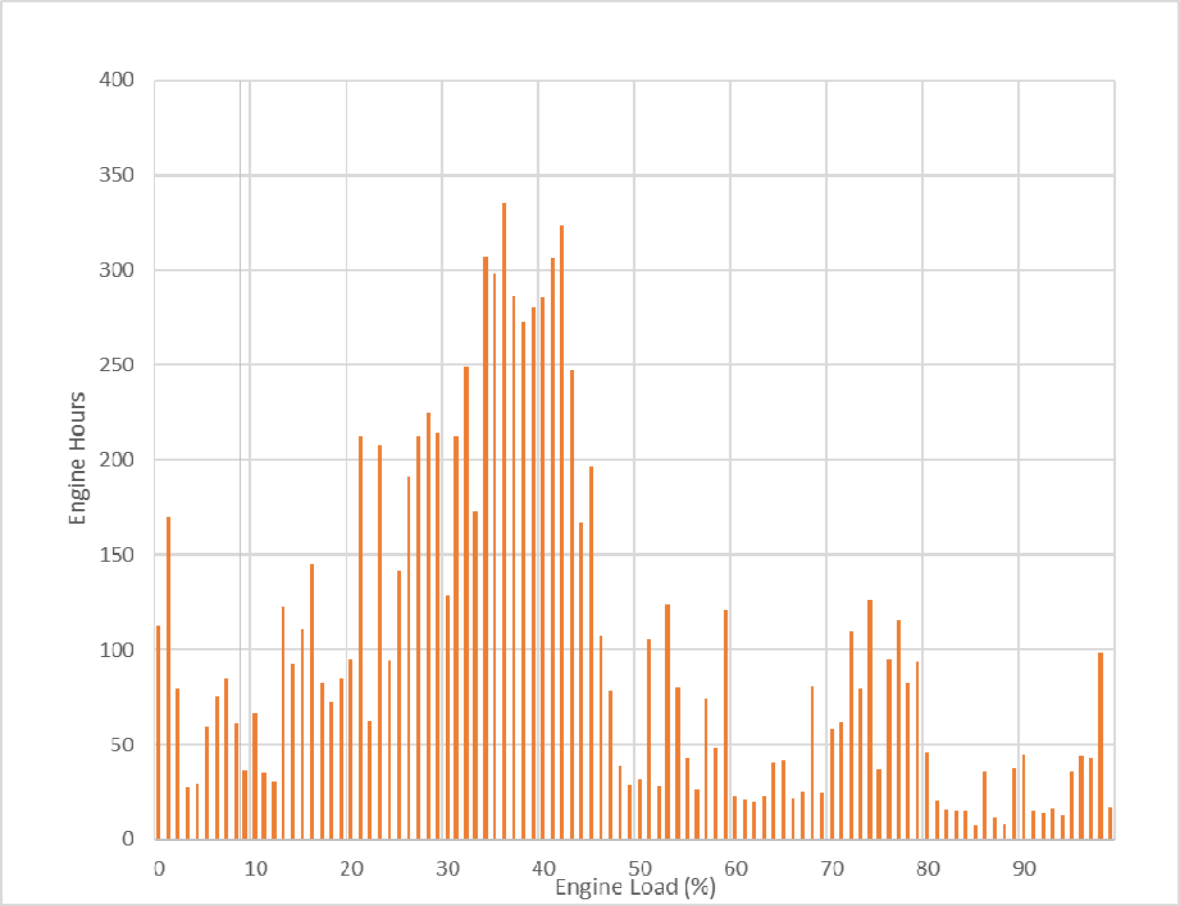

Figure 8 Lower Mississippi Profile #2

The estimated fuel savings over a 10 year period for the above load profiles are:

Mechanical v. Electrical Opex Cost Savings		
Fuel Savings / year	31,637	gallons
Fuel cost per gallon	$2.00	$/gal
Fuel Savings / year	$63,273	dollars
Urea Consumption/yr	22,681	Gallons
Urea cost per gallon	$4.00	$/gal
Urea Savings / year	$90,724	dollars
Total Savings / 10 years	$1,539,975	dollars

Figure 9 Op-Ex Savings for Profile #1

Mechanical v. Electrical Opex Cost Savings		
Fuel Savings / year	12,985	gallons
Fuel cost per gallon	$2.00	$/gal
Fuel Savings / year	$25,969	dollars
Urea Consumption/yr	21,934	Gallons
Urea cost per gallon	$4.00	$/gal
Urea Savings / year	$87,738	dollars
Total Savings / 10 years	$1,137,071	dollars

Figure 10 Op-Ex Savings for Profile #2

Diesel electric propulsion provides these savings from a variety of benefits. Propulsion machinary for each 2400 HP towboat is listed below:

Typical 2400HP Machinery:	
Prime Mover:	2 x 1200HP Tier IV Engines
Generator:	2 x 200kW Tier III Generators

2400HP Diesel Electric Machinery:	
Power Generation:	4 x 800hp Tier III Generators

For the mechanical towboat, at any engine load from idle to 100% you are running at a minimum three (3) engines to maintain full manuevering plus the house electrical load. The diesel electric however is running an optimized number of engines. From idle to about 25% load only one engine is required to be running to provide propulsion to two shafts plus the house electrical load to the vessel. Only at much higher loads (typically > 80%) does the diesel electric lose some of its efficiency gains over the mechanical propulsion system.

Capital costs between the diesel electric propulsion system and a comparable Tier IV mechanical propulsion system are nearly identical with current equipment costs.

Beyond Fuel Savings

Diesel electric propulsion systems also provide benefits beyond fuel savings. During the design process, consideration should be given to items like redundancy of propulsion systems, urea consumption and storage, and engine maintenance.

The diesel electric also shines with respect to redundancy and safety. With any engine able to provide power to either propulsion motor, an operator can minimize the impact of a prime mover failure. On a mechanical system, the loss of a prime mover results in the loss of 50% of the propulsion and an entire shaft. On the diesel electric towboat, the loss of a generator set only results in the lost of 25% of the maximum available power while still being able to provide power to both shafts. Similary, with the loss of a generator on a mechanical system, the vessel now has no back-up for house and auxillary loads. The diesel electric system can keep providing power with multiple back-ups for the electrical generation.

Using multiple Tier III generators removes the requirement for Tier IV engines, with SCRs or EGRs required to meet the emissions requirements. If a vessel is using urea for SCRs, with a typical DEF dosing rate of 5%, a new vessel design has to accommodate a urea tank, the SCR, and the additional exhaust piping.

Another benefit comes from engine maintenance and schedules. By reducing the number of engines running to an optimal number, diesel electric propulsion reduces the number of engine hours spent at partial loads. A vessel that spends 40% of its operation time at less than 50% propulsion load can keep hours on two engines instead of three when compared to a mechanical driven system. In addition, because the vessel only has one type of engine on board it can reduce the number of spare parts and equipment for both the vessel and shore side support.

Conclusion

Diesel electric, just like azimuthing drives, may not be the best solution for all operational profiles on the river. It does, however, offer distinct advantages in many scenarios and should be considered as part of the overall decision making process when designing a vessel. Benefits extend beyond just operational cost savings by also providing increased operational safety and redundancy for towboats.

TSGI would like to thank the Marine Division at ABB for assistance with the electrical design of the concept diesel electric towboat and providing some of the technical information for this article.