All Electric and Hybrid Electric Drive How to Push a Sailboat

by Mike Gunning
Electric Yachts of Southern California

The sail boat with an internal combustion engine (ICE) is a hybrid boat. Primary propulsion is the sail using natural wind power. The ICE is the auxiliary propulsion providing power in confined areas, when there is no wind, and possibly against a wind and or current. For practicality, I will assume that sailors do not normally drive their boats against the current and wind but would likely stay at anchor or in the slip waiting for a more advantageous time to make passage.

Options

It is a sailboat so it is assumed that the operator will want to first sail rather than motor. Also most sailboats under auxiliary power are displacement boats due to the nature of the hull and displacement. These are the auxiliary power options: Outboard motor – Electric, Gas, Diesel, or Propane and Inboard motor - Electric, Gas, Diesel, or Propane

In this paper, my intent is to discuss the characteristics of the inboard systems only. Now let's look at these options and what they really are. The motors are really two unique systems.

Electric Motor

The electric is an electro mechanical motor that uses electric current to spin a rotor surrounded by a stator that then directs that rotation to the shaft. There is a battery (power storage system) that holds the stored power which the motor uses. There are controls usually by wire system and communications by wire to the helm monitoring system. Most modern systems use computer supported controllers to manage the motor. The motors are either AC or DC and run on DC low voltage currents of 12v, 24v, 36v, and 48v or high voltage currents of 72v, 96, 110v, or 220 (the later two will be AC currents). The 48v PMAC motor has become the motor of choice for most new sailboat systems. There is no gear required as propeller rotation is directed by running the motor in either direction. Often there is no cooling system necessary for electric motors. There is a battery storage system that also requires a charging and monitoring system. The nature of the electric motor flat torque curve normally enables the boat to typically have a more powerful propeller.

Advantages of electric motor:

- Few moving parts and very low maintenance cost
- Quiet running
- Almost instantaneous power without need to warm up
- Powerful flat torque curve with power available at slow speeds
- Remarkable slow speed control – 150 to 600 RPM with full control
- No fumes
- Easy sailing with motor assist improving point of sail and speed
- Regeneration of power under sail at speed

Disadvantage of electric motor:

- Limited power storage facilities in the heavy batteries impact range

Internal Combustion Engine (ICE)

The ICE is a mechanical system that uses the rapid expansion of a consumed fuel contained in the chambers of the engine and uses significant mechanical devices to change the direction of the power into a rotation force. From that rotation there is a need for a gear to provide forward reverse and neutral. The engine also requires additional systems: cooling of the engine, removal of the hot exhaust byproducts, electric starter including battery, lubrication system, alternator, and fuel storage system including pumps and filters.

Advantages of ICE motor:

- Extraordinary power storage in fuel system
- Powerful engine (note support systems reduce the power available for propulsion)

Disadvantage of ICE motor:

- High maintenance cost and repair – skill mechanics required
- Not quiet but can have significant noise reduction measures
- Engine requires warming up prior to applying power to the prop
- Engine requires high RPM to deliver power to the shaft – This requires shifting of the gear in and out of neutral at slow docking speeds
- Significant fumes and exhaust
- Uncomfortable motor sailing as an assist to sail power due to high RPM needs of engine.

How the Electric and Diesel differ

Power is power and the propeller does not care how the rotational power is created. Or does it? The electric motor has the significant advantage of a remarkable flat torque curve through most of the RMP range. Because of this capability, electric motors can normally drive more powerful propellers than comparable powered diesels. Advantage electric

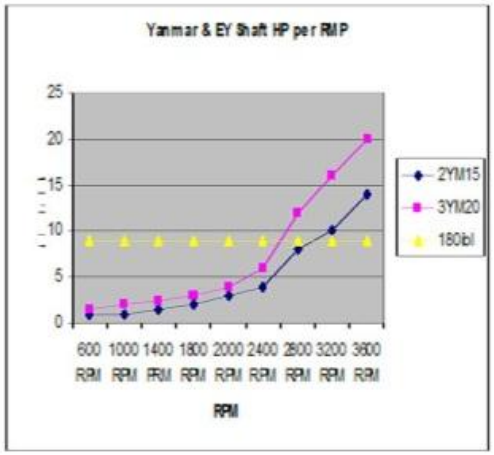
Electric motors low speed operations around the anchorage or in and out of dock is much improved over the diesel. There is no lugging the diesel and moving the transmission in and out of gear – there is no gear.

Advantage electric The electric has a small power storage capacity as there is limited space and weight capacity for batteries on board. The Diesel has significant power storage in the form of liquid fuel. I often describe the power storage of a typical sailboat battery pack as having a 2 gallon fuel tank.

Advantage diesel Electric propulsion allows the use of low power slow propeller rotation that can improve your pointing and reduce hull drag. This is not motor sailing as done with a diesel engine, but rather sailing with motor assist at very low speed propeller rotation. Advantage electric

The electric motor has the capacity to generate power by sailing. This is accomplished by having the controller on recognizing the propeller rotation driving power into the battery pack. The power regeneration by the motor is practical with a larger propeller surface and at speeds greater than 5 knots. Advantage electric

What does that mean to the sailor? If you are a sailor who runs the diesel system at high throttle and push the boat at hull speed, than you need to stay with diesel. If you are a sailor who use the auxiliary as little as possible, normally not exceeding 70% of hull speed, wait for favorable tides, currents, and wind for passage making, than electric is an option.



The graph illustrates the power curve of the electric and diesel. The data is taken from vendor supplied information and is specific for the particular diesel engine and electric motor but is a good example of the typical power curve of any diesel and electric system. When analyzing this data, you should apply the practical experience of your boat and your engine to understand how the systems interact with the hull, transmission, and propeller. The power your engine applies to the propeller is converted to forward and reverse propulsion and all variables come into play.

Day Sailing

The use of the auxiliary propulsion is slow speed motoring around the slip and out of the harbor. Normally this is a limited distance and requiring slow speed control. In light winds, when sailing around 50% of hull speed, it takes about 250 to 500 watts to increase the boat speed about 2knots. Add the advantage of slow prop rotation reducing drag and providing better pointing and turning makes the electric a better option than diesel.

Racing

For day sailing the advantages of slow speed operations in close shore racing is an advantage to electric. In the environment of close in off shore racing the ability to reduce weight with high tech LiFePO4 batteries and light weight motor is a significant weight reduction over diesel.

Cruisers

With the cruiser, wind and sails are the only practical propulsion. There are no fuel stations off shore. Or are there? None for the diesel but wind, solar, and sailing regeneration provide power to the propulsion battery bank and also house needs. The use of the diesel running in idle to provide an additional few knots is not efficient use of power and not good for the diesel as it loads the engine. Finally the diesel alternator as a source of house power is very inefficient. For the cruiser, we do not recommend electric only for major cruising but the electric hybrid solution provides a significant advantage over diesel only.

Lake Sailing

Like day sailing, the use of the auxiliary propulsion is slow speed motoring around the slip. Add the advantage of slow prop rotation reducing drag and providing better pointing and turning makes the electric a better option than diesel.

Two Types of Hybrids: Serial and Parallel

The **serial hybrid** has electric only propulsion. The diesel engine is found in the generator which drives power into the batteries from which the electric drive motor pulls stored energy to spin the propeller. A well designed system should also regenerate power while under sail. The generator and the battery system are also available for house use. The generator is either DC or AC, the AC being much less expensive to acquire. The generator will run only

when necessary to replace the power in the battery pack and drive power to the motor. The serial hybrid is best suited for the larger sail and powerboat. But many smaller sailboats, less than 40 feet, use small non marinized portable generators to support battery bank power recharge needs.

The **parallel hybrid** is configured so that either the diesel engine or the electric the electric motor provide the propulsion. The electric motor is also the generator. The electric motor in a parallel hybrid as a generator will be restricted in its generation capacity by the power of the diesel engine to drive the generator while also under power. Two significant advantages of the parallel hybrid are redundant propulsion systems and significant generator capacity at a significantly lower cost compared to a traditional generator. You recharge three ways: sailing, diesel underway, and diesel while stationary. The capability of the diesel while propelling the boat and turning the motor/generator is constrained by the hp of the diesel. When you run the diesel to put power back into the battery pack while pushing the boat, the replacement time will vary. You can expect a well designed system to be about two hours of diesel propulsion/generation to replace one hour of electric only propulsion. The parallel hybrid is best suited for the 30 to 40 foot sailboat.