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electric drive *for* m

by Rick Lambourne

IT'S A GLASSY CALM DAY SOMEWHERE NORTH OF HERVEY BAY AND *SCHOOL'S OUT,* A RECENTLY LAUNCHED ORAM 44c catamaran is motoring quietly north. There's only a low hum from the twin electric motors and a muffled sound from the well-insulated diesel generator. The washing machine is doing the weekly wash, bread is baking in the breadmaker and there's plenty of hot water for a shower. The electric kettle is on for a coffee. Apart from energy from the solar panels, the total fuel consumption is 1.8 litres of diesel per hour.

THIS IS THE SHARP END OF the increasing move towards electric and hybrid (diesel-electric) auxiliary power for multihulls. Lagoon have had a hybrid version in production for several years and Fusion have just launched their own hybrid. At the owner-builder level people are experimenting with electric motors, diesel generators and battery banks as an alternative to twin diesels or twin outboards. Being a prospective catamaran builder myself, at the 'anything is possible' stage, I decided it was time to have a close look at what is going on in this field.

The elements of an electric drive system are simple enough. The electric motors can be outboards, or inboards with either shaft drive or saildrive. Outboard motors may be either

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ultihulls

conventional outboards converted to electric power or outboards designed from the start for efficient electric drive such as the Torqeedo. An inboard set-up would normally involve a small permanent magnet DC electric motor with a belt-drive for speed reduction, onto a conventional shaft. Companies such as LMC, Asmo Marine, SolidNav, Vetus and Bellman provide a complete motor/controller/belt drive set-up that can be installed in place of a diesel engine.

The Sonic electric saildrive unit, made by Sillette in England, pairs a Lynch Motor (the original pancake DC motor) with a custom saildrive leg. It can be direct drive or belt-reduction drive, depending on the motor chosen and the required propeller speed.

Motors

DC electric motors are mostly permanent magnet motors with a diameter larger than their length, typically

First test run with twin Torqeedo outboards. (main pic above left)

Torqeedo controls throttles – magnetic keys and readout of battery charge – remaining range – speed and input wattage. (top)

The designer steers while the skipper listens to the sound of silence. (above)

Swing arm in down position. (above left)
Torqeedo outboard leg mounted on swing arm – fully up. (above right)

24, 36 or 48 volts, with a speed range from 1000rpm to 3500rpm and efficiencies of 70-95%. They are compact and light compared with diesels, and have the advantage of developing constant torque regardless of revs, making low-speed manoeuvring very positive. No gearbox is required: the motor simply stops and spins the other way.

Electric outboards have been available for some time, but have had their limitations. They were either trolling motors, designed for low speed, or conventional outboards converted to electric power, which have limited efficiency, largely because the propellors are too small to develop the high thrust required for pushing a multihull. The German Torqeedo outboards though are designed from the start for efficiency, with large diameter, slow-revving propellers, and are now available in a size suitable for multihulls. The new Cruise 4.0R has a four kilowatt motor with a remote control panel with built-in GPS, which displays remaining battery charge, range, speed over ground and input power. The 48 volt motor develops thrust equivalent to a 9.9hp petrol outboard.

Controllers

An electric motor requires an electronic controller, which regulates the amount of electricity going from the batteries to the motor, mainly in response to the throttle, but it can also depend on resistance, component temperatures and battery charge. The controller also enables the motor to go forward and reverse, so no gearbox is required, limits the top speed and may also allow regenerative charging. It takes the nominally fixed voltage from the power source (batteries) and produces the variable voltage supply needed to control the motor speed, in response to signals from the throttle, which is a potentiometer. The voltage conversion is done very efficiently using PWM (pulse-width modulation) techniques giving very smooth speed control.

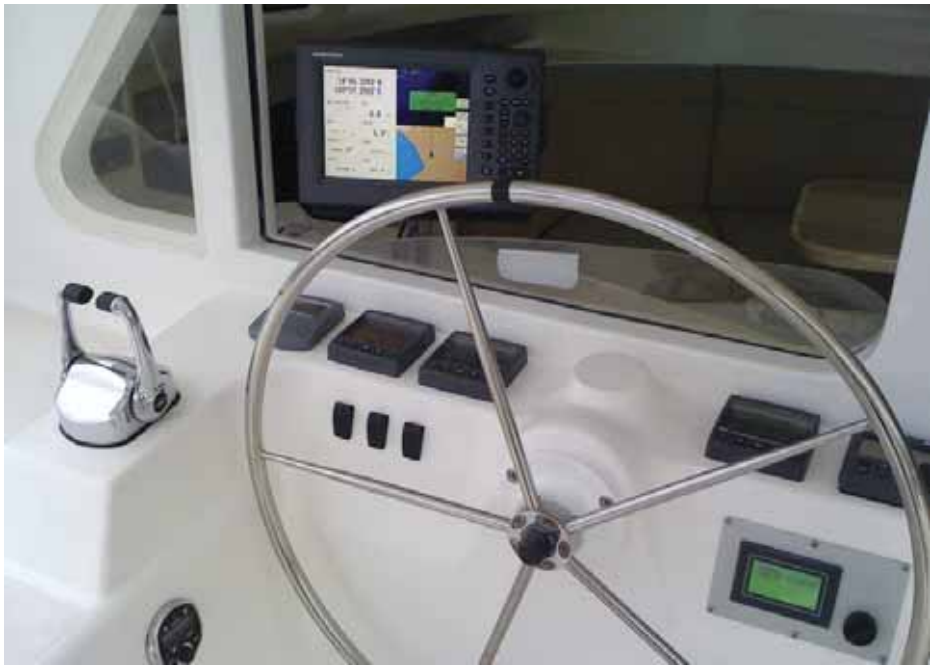
All these components are available from the manufacturers or from various suppliers who specialise in electric drives for vehicles and boats. So, as long as you have a good understanding of electrics, or an auto-electrician in the family, it should be possible to install an electric drive in your multihull.

Batteries

An electric drive system will require substantial battery capacity, and as we all know batteries are heavy and multihulls don't like extra weight. The decision as to how much capacity is ideal will always be a compromise between maximising range and minimising weight. The other decision to be made is the compromise between heavy but relatively inexpensive lead-acid batteries and lighter but more expensive lithium batteries.

The standard 'wet' lead-acid battery is designed to start your motor (high discharge) then recharge gradually. It will self-discharge fairly quickly and should not be discharged to less than 50% capacity or its life will be shortened. It will provide about 200-300 discharge/charge cycles. The deep-cycle version is more suited to house battery use, but may not provide the high discharge rate needed for electric drive systems. The AGM (absorbed glass matt) battery has better characteristics and doesn't give off hydrogen while charging, a big advantage if you are a smoker. The lead-acid battery with the best combination of deep-cycle and high-discharge qualities is the thin-plate-pure-lead type (a variation on the AGM battery), such as the Optima battery (thin plates in a cylindrical formation) or the Odyssey battery, which has flat plates in a more conventional shape. Claude Desjardins of Torqeedo Australia has been 'thrashing' some Optima batteries for three months and says "I'm pretty happy with the Optima batteries, they are still going strong after everything we've done to them."

The next step up in energy density (amp-hours output per kilo of weight) is the nickel-metal-hydride battery. This is the battery type originally used by Lagoon in their hybrid catamaran, but has been found to have recharging problems and can be unstable (remember the fire which nearly destroyed *Playstation*?). "It is widely accepted that nickel-metal hydride is an interim step to lithium-based battery technology". (www.batteryuniversity.com)



Lynch motors – permanent magnetic DC motors suitable for marine drives – from 2.25 to 16.8kW (3-22hp). (top)

Controls on the Fusion Hybrid. Note conventional throttles and touch-screen display for electrical system. (centre)

Silletee sonic saildrive unit with reduction belt-drive electric motor. (above)

Torqeedo Cruise 4.0R electric outboard.

The Lithium Ion battery has the best energy density, straightforward charging requirements and no memory effect. It does require a protection circuit to maintain voltage and current within safe limits (known as a battery management system). Several chemistries are available, the safest being Lithium Manganese and Lithium Iron Phosphate (LiFePO4), which are more stable than the original lithium ion battery. Lithium Iron Phosphate batteries are now available in Australia in two forms: the Thunder Sky battery from China, which "do not have the volatile thermal issues that Li-ion batteries have" (Thunder Sky website) and the BMI battery from Taiwan, a very high-quality battery available in a range of capacities.

Not only are these batteries about a third the weight of lead-acid, but since they can be truly deep cycled (up to 2000 times) down to 20% capacity, you will only need 62% of the nominal capacity (compared with lead-acid), meaning your battery bank could weigh about 20% as much. This is the real breakthrough in making electric drive truly viable, one we've been promised for years, and the relatively high price is simply the cost of being an early adopter.

Generating power

A good-sized bridgedeck cabin roof, extended over the cockpit, can provide space for about 750 watts of solar panels. For a weekend boat with a good battery bank this could provide enough stored energy for about three hours of motoring. The limiting factor will be the capacity of the batteries. For a boat in continuous use solar panels and wind generators alone are only going to give enough energy for the truly dedicated. In 2007 a 14m power catamaran, *Sun 21,* crossed the Atlantic using only solar power, so it is possible to drive a boat with renewable power alone, but the boat's electrical systems would have to be designed for the utmost efficiency.

Some way of supplementing power when it is needed is desirable. There are small 12 and 24 volt DC petrol and diesel generators of 100-150 amps output available. These are designed for battery charging but will not provide enough power to run the electric motors and the house systems. However, with careful planning they would keep a large battery bank topped up, which would allow enough motoring time for entering and leaving port. A true hybrid system should have a generator large enough to provide power for motoring, at least at half speed, without depleting the batteries. There are very few DC generators available in this size for marine use, but they are available.

Most conventional onboard generators run at 240 volts AC to supply power for appliances, refrigeration, watermaker, aircon, compressors and other gear. They have to run all the time while these loads are in use, often supplying more power than is required. In contrast, a DC generator starts automatically when the battery level drops below a preset voltage and cuts out when the batteries are fully charged. Power for 240 volt appliances is provided as required from the battery bank through an inverter, although a lot of onboard needs can be met using DC equipment developed for the marine and RV markets. Imagine how surprised you'd be to find a 240 volt generator in the boot of your new car!

Hybrid systems

A typical multihull has twin diesel engines and a separate generator for house loads. It makes a lot more sense to have a single diesel generator which provides power for both propulsion via twin electric motors and for house loads. This system has been used for over a century in ships and submarines and the efficiency and lighter weight of the hybrid system is being increasingly recognised by

designers of small ships and boats. The advantages are:

- The variable speed generator is always turning at the optimum speed for a given load
- The Genset can be placed in the best location and completely sound-insulated
- The electric motors can be designed to operate at speeds most suitable for props, so no transmission is required

and Caine 43ft eLeopard hybrid with a single 25kw (33hp) generator has a top speed of 8.2kts while the standard version with two 30hp Yanmar diesels does 7.5kts.

Two companies provide integrated hybrid systems: Ossa Powerlite and Fischer Panda.

The Ossa Powerlite diesel genset generates at 120-800 volts DC and feeds it to the power distribution panel. Propulsion motors are liquid-cooled

volt AC shore power is converted to DC by the power distribution panel.

The Fischer Panda generator creates power at 400 volts AC at 3,000rpm, or can provide DC for battery charging at 1600rpm. Domestic power is provided from the batteries by an inverter. Propulsion motors are permanent magnet, nominal 440volts AC, run through a controller, at a nominal speed of 1200rpm, constant torque, operated by a joystick.

- The torque-power curve of an electric motor is a much better match for propulsion requirements than that of a diesel
- Onboard systems can be better integrated

With a generator operating at its most efficient speed for any load and electric motors delivering maximum torque even at low rpm, the result is a **smaller power requirement for a given performance level.** This explains why the Robertson

permanent magnet synchronous DC motors, running at max 1100rpm (direct drive), up to 98% efficient.

The joystick throttle controls the motors through the communications buss.

Touch-screen displays show the status of all parts of the system and provide for configuration and programming of HVAC, watermaker, etc. These accessories operate at 240 volts DC, which is safer and more stable than shore power. When plugged in at the marina the 240

Current Sunshine – ex *Bullfrog* – on her first test cruise with the Torqeedo outboard motor. (top)

Ossa Powerlite generator and Centrek exhaust separation system in the Fusion Hybrid. (above left)

The new Lithium Iron Phosphate battery bank for *Room With A View* being monitored. (above centre)

Powermaker Cruise 5KW 24 volt marine diesel DC generator – manufactured in Australia by Watts2C. (above right)

School's Out

Bryan and Rowena Beutel have recently launched their catamaran *School's Out,* an Oram 44C design stretched to 45ft. From the start they wanted a hybrid system: electric drives, a good-sized battery bank and a diesel DC generator. The original engines were direct-drive submersible engines (or pod motors) mounted on swinging arms against each hull. When these gave disappointing results and had problems with leaks, Bryan switched to Torqeedo outboards but mounted them on the swinging arms because these had worked so well. I was lucky enough to be on board when the first trials were done and the results were impressive (see chart at end of article). The two Cruise 4.0R motors gave a top speed of 6.0kts at 4000 watts per motor and a cruising speed of 4.0kts using only 1250 watts per motor. Low-speed manoeuvring in the marina was excellent.

School's Out has a sophisticated electrical system. Power is supplied by four 60 watt solar panels (soon to be eight) and a Volvo Penta 12.2hp diesel genset giving 5.4 kilowatts at 48 volts for the main battery bank and 1.3 kilowatts at 12 volts which charges the separate 12 volt battery bank dedicated to genset starting and anchor winch. The main battery bank is lead-acid, of the TPPL variety, because they give adequate results at a reasonable cost. The capacity is 230 amp-hours at 48 volts. Most of the boat's electrical appliances are 240 volt: the fridge, freezer, hob, microwave oven, TV, washing machine and even the electric kettle all run through a 3.6 kilowatt inverter from the 48 volt battery bank. They find that running the genset for 15 minutes morning and evening keeps the

Volvo Penta 12.2hp diesel and 5.4kW 48 volt generator.

batteries topped up and gives them hot water. Once a week they run it for a couple of hours, do the washing, bake bread and give the batteries a boost.

When using the electric motors at low speeds the batteries supply the necessary power, and there is only a slight hum from the motors, but after 10 minutes at higher speeds the genset cuts in to take the load and recharge the batteries.

Current Sunshine

Chris Baker, owner of *Current Sunshine* (ex *Bullfrog*) is one person who believes it's possible to live on sunshine alone, for auxiliary power at least. He has almost finished installing solar panels, Thunder Sky battery bank and through-hull Torqeedo Cruise 4.0R outboard. He sent me a detailed description, so I'll quote him verbatim (pun intended).

"The engine bank is 200ah at nominal 50v and at full throttle this gives me two hour's motoring. Even though this doesn't feel like much it stretches remarkably when you reduce the throttle – so at a speed of 4.5kts, which is around 1500 watts, I can run for five to six hours, which is way more than I'd ever run the outboard in the year or so before I began these changes. And the power consumption continues to drop away even more dramatically if I drop down to three knots – which requires only about 500 watts of power. And a quick bit of figuring points to around 15 or more hours at this speed.

I'm basing these numbers on an 80% drawdown of the battery bank – and the LFP batteries are fine with such a draw down – it doesn't phase them at all.

And the other nice thing is that they can sit at this low level of discharge without damage – I don't have to rush to charge them back up again, which is a good thing because if I do draw them down so far, I'll be waiting at anchor for maybe three weeks of sunny days to get them back up again! And that's a product of my wish to be totally self-sufficient and to be able to run largely on energy from the sun.

Solar panels for decktread helps keep windage low and allows this boat to maintain her throughbred lines – having been raced as Bullfrog and Verbatim in the 80s, many people know her and I'm sure would be disappointed to see her sprouting targa bars and solar panels structures just to suck in some energy. Solara solar panels have a stainless steel sheet as a base and the cells are directly attached to this and protected by a dimpled clear layer which you can walk on. Being able to walk on them means that the deck space is not compromised – well not much anyway – but they are more slippery than regular decktread. There are seven of these that under ideal conditions would produce 300 watts.

Fusion electric drive 21hp (15.6kVA) electric motor mounted directly on to the saildrive – and a lot of empty space. (left)

BMI's new LifeTech battery – coming soon. The touch-screen will allow you to read out all battery data – faults and history. (below)

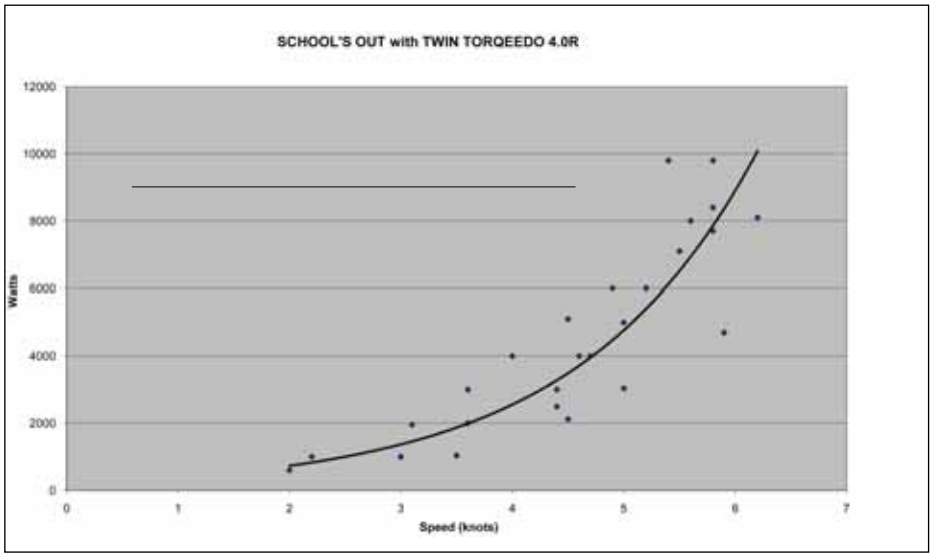
Chart of speed against total motor wattage. The wide spread is due to wind and tide influences. (bottom)

After meeting the house load there wasn't a lot left over to charge the engine batteries, so I've since added two UniSolar flexible panels each 68 watts. These I store in the floats and use when at anchor – or on light wind days when I can roll them out of the tramps without concern for them blowing away.

With these panels helping as well the house batteries can be charged by 10 or 11am each day and for the rest of the day the excess is available to charge the engine batteries. All the panels are 12v and feed direct into the lead-acid house bank.

The engine batteries (LiFePO4) have none of the charging losses that you find in lead-acid batteries. That is, with lead-acids you need to put back about 10% more power than you took out. So to get back 100 amp-hours you need to put 110 amp-hours into the battery. With the LFPs it's as near to even as I can figure with the instruments that I have to measure state of charge.

For rainy/cloudy days I have a wind generator which is normally stored away. I only rig it when needed to avoid more top hamper. Its dynamo can also be set up as a towing generator – I've not tried this yet. For a while I had an Epod submersible



SCHOOL'S OUT WITH TWIN TORQEEDO 4.0R

Speed	Watts	Headwind
2	600	
2.2	1000	9.2
3	1000	
3.5	1040	
	1200	
3.1	1960	9.9
3.6	2000	
4.5	2120	
4.4	2500	
3.6	3000	10.3
4.4	3000	
5	3040	
4	4000	11.6
4.6	4000	
4.7	4000	
5.9	4700	
5	5000	
4.5	5100	12.1
4.9	6000	11.8
5.2	6000	
5.5	7100	
5.8	7700	
5.6	8000	
6.2	8100	
5.8	8400	12.2
5.4	9800	
5.8	9800	

electric motor and it had some regenerative capability and so I didn't need to consider a towing generator. It was poorly engineered and I've abandoned this motor in favour of the Torqeedo".

Fusion hybrid

Fusion have recently launched a sophisticated hybrid (diesel-electric) version of the very popular Fusion 40, which uses Glacier Bay's integrated hybrid system, based on their Ossa Powerlite range of products. The boat is powered by a 26kW variable speed Mercedes diesel generator (240 volt DC) which drives two 21hp (15.6kW) motors which run on 400 volt AC power, driving through Sonic saildrive legs and Gori three-bladed props. Power for the motors, appliances and air conditioning is provided by an inverter. There are only a couple of house batteries for lighting and other 12 volt applications: this system requires the generator to be running when motoring and when house loads are high. Gas is used for cooking and water heating plus the generator or shore power when in marinas.

Controls are all operated with touch pad technology plus a more conventional fluid shift.

Jim Gard reports that the low-speed torque of the motors is impressive and the boat is eerily quiet under power, partly attributed to the custom built Centrek exhaust separation system on the generator.

Whilst taking the vessel from launch area to the marina at 850rpm four knots was achieved. Whilst overall motoring speed is expected to be a knot slower than with diesels, it is believed the fuel consumption will be less than half that of the diesels.

Sea trials were being undertaken as we go to press, and we hope to bring you a full report on the Fusion Hybrid in a future edition – Ed.

Room With A View

This well-known racing catamaran is nearing completion of a refit which includes conversion to electric drive. When completed it promises to be one of the most advanced all-electric boats in Australia. Power for both propulsion and house needs will be supplied by a BMI 48V 240Ah Lithium Iron Phosphate battery bank which features advanced PC monitoring/ diagnostics of all batteries, a system which can test each of the 384 separate cells twice a day and report any faults by SMS to the owner's mobile phone!

Charging will be done by solar panels and a triple-alternator diesel genset.

The battery bank has the ability to be fast charged to 90% capacity in only 15 minutes. The all-up weight of the BMI batteries is 198kg, compared with over 500kg for the lead-acid batteries originally considered.

BMI are developing an even more advanced battery series which will feature CAN (Controller Area Network) bus and LCD User Interface Touchscreen on the end of each battery. This allows you to read all battery data, faults and history at the battery itself.

The future

Judging by what I've seen of recent developments there's a huge amount of interest in this subject and a lot of enthusiasm for experimenting. I'm expecting to see further improvements in the technologies, especially the integration of onboard systems and the quest for efficiency. The average petrol or diesel drive is only about 10% efficient (measured from engine to thrust) while Torqeedo rates its outboards at 51%.

In hybrid installations the DC motor may run at 97% efficiency but losses at the generator and drive train reduce this drastically, so there's room for big gains to be made here.

Watch this space!

RESOURCES

Electric motors

Lynch Motor	www.lemcoltd.com
Asmo Marine	www.asmomarine.com
Solidnav	www.solidnav.com
Vetus	www.vetusdirect.com
Bellman	www.bellmann.nu
Sillette	www.sillette.co.uk
Torqeedo Outboards	www.torqeedoaustralia.com

Batteries

Battery University	www.batteryuniversity.com
Odyssey	www.odysseyfactory.com
Optima	www.optimabatteries.com.au
Thunder Sky	www.evworks.com.au
BMI	www.lithbattoz.com.au

Generators

Christie Engineering	www.christieengineering.com.au
Onsite Power	www.onsitepower.com.au
Watts2C	www.watts2c.com.au

Hybrid systems

Ossa Powerlite	www.ossapowerlite.com
Fischer Panda	www.fischerpanda.de/eng

Suppliers

Electric Motorsport	www.electricmotorsport.com
EVParts.com	www.evparts.com