Advanced electrical training

Online course generates high marks

Marine electrical specialists Nigel Calder and Jan Athenstäte have introduced an online Advanced Marine Electrics course that compliments their basic 101 class. *MEJ* asked NMEA instructor John Barry to work through the curriculum and comment on the content and value for professional technicians and installers.

In short, he concluded that the "well-presented classes are quite good and draw from the wealth of knowledge of the authors, who are longtime mariners and experts on standards. The format varies from written articles to videos." Below, Barry provides some details.

BY JOHN BARRY

Facing page: *Digital switching reduces the amount of wire used to build a boat. Serviceability is impacted, making documentation of installed equipment all the more important. Critical systems need redundancy since digital switching introduces additional potential points of failure.*

(Courtesy Yacht Inside, BoatHowTo)

The Advanced Marine Electrics class offered by BoatHowTo is divided into three sections: Installation and Safety; Power Generation and Storage; and Networks and Technology Trends. Section 1 includes five subsections: Grounding; Shore Power AC; Onboard AC; Corrosion; and Lightning Protection. Section 2 contains Alternators; Generators; Lithium-Ion Batteries; and Optimized Energy Systems. Section 3 teaches about NMEA Data; Digital Switching; and Electric Propulsion.

Section 1: Installation and Safety

The AC power subsections are basically training to comply with ABYC (American Boat & Yacht Council) and ISO (International Organization for Standardization) requirements. The authors know both the European and US components, like shore power, generator power and inverter power, switching between them and applying loads—also transformers and overcurrent protection and how they relate to galvanic and stray current corrosions. Safety ground and ELCI (Equipment Leakage Circuit Interrupter) protection are also covered. Some changes in ABYC requirements have resulted in strange results, such as new ground fault requirements for shore power that have led to problems, from dock breaker tripping to electrocution drowning hazards. The course explains why this happens and contains the latest information. All in all, the AC sections are great.

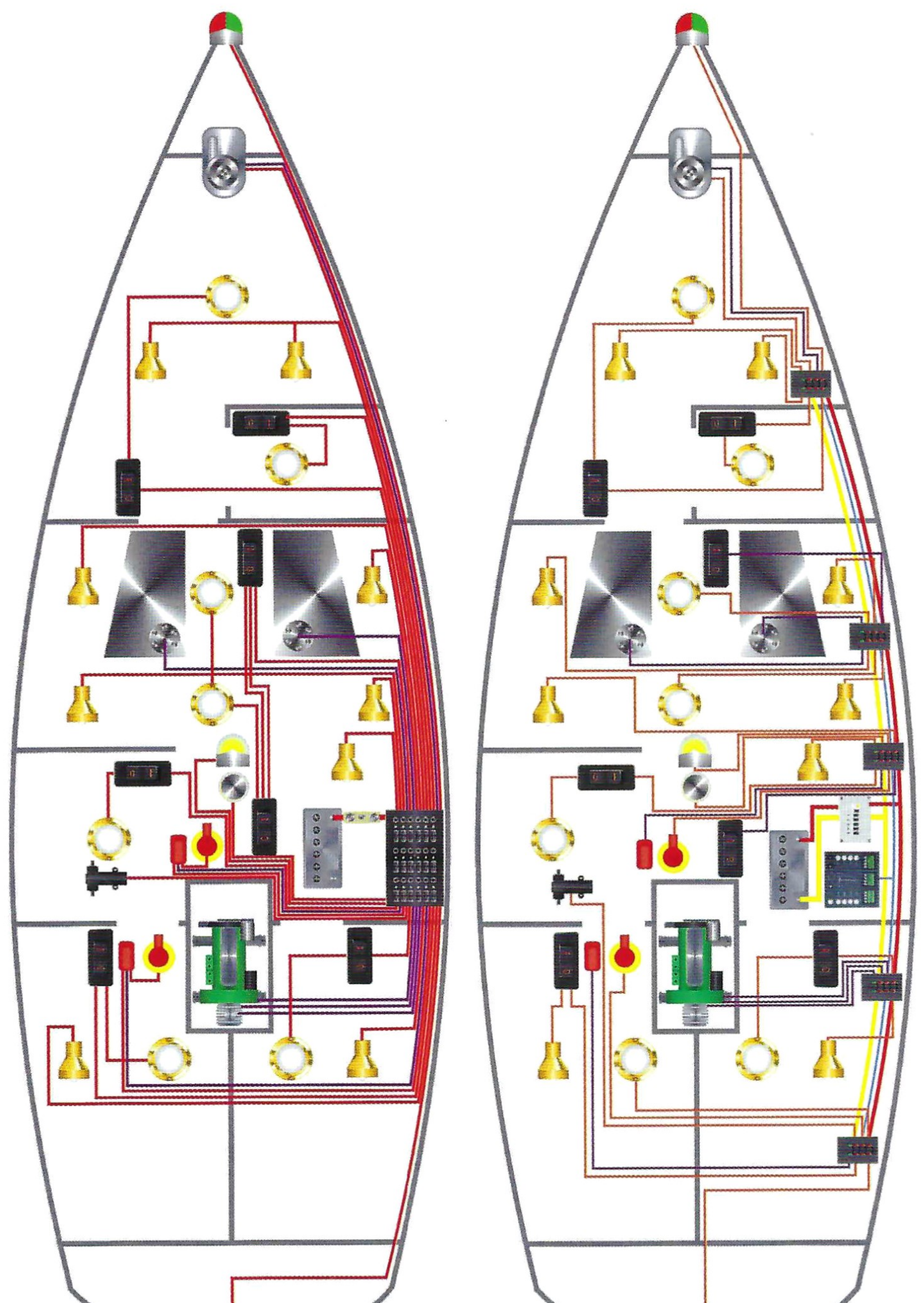
The corrosion and stray current discussion is thorough. It's not as deep as ABYC goes in their corrosion program but is good information for the boat maintainer. Discussion of different metals and alloys is aimed at understanding what to buy for repair or refit. They mention many important facts, like use of all stainless hose clamps. They even recommend brands that are available in the marketplace. Explanation is given for sacrificial anodes and why they exist, how they fail and how to test them. Cathodic action is explained in theory and practice. Various corrosion types and anode sizing, etc. are referred to onboard power generation experts. Recognizing and resolving problems are the thrust of this section.

Section 2: Power Generation and Storage

This section starts with alternators. A discussion of heat and voltage leads to information about pulley torques. With modern, very-high-output alternators, regulation is more necessary. Yes, we want to size it to meet our expected loads and battery banks, but we also must ensure that the motor is not overloaded by the big alternator. Looking at the charge curve for the alternator and the power curve for the motor, methodology is given for a safe installation. This is a fascinating and useful discussion for boat owners or tinkerers, but is beyond the scope of what a typical installer needs to know. Nonetheless, the explanations are understandable for a complex topic.

Of course, the drive belt is also an important factor for high-powered alternators. When a spinning alternator starts making 200 amps or more, the torque is significant and the belt must not slip. Output of alternators depends on RPM and RPM depends in large part on the pulley ratio. Determining the pulley ratio and belt types are covered. Maintaining and inspecting pulleys are part of the drive-belt subsection. In the generating electricity section, there is detailed discussion around energy usage. The method for calculating run times and generator capacities includes a lot of charts. The power curve of the motor is changed by the addition of a belt-driven load, like an alternator. To attain maximum fuel economy, an engine usually runs at a fairly high load. By adding an alternator, the engine can run more time at a higher efficiency, sometimes increasing overall efficiency. Real-world results vs

Traditional Wiring vs. Digital Switching



Traditional wiring: For each load there is a pair of wires going back to the switch panel (only the positive wires are shown here)

Digital switching system: Power distribution modules (PDM) are remotely controlled from the switch panel, significantly reducing the required amount of wiring.

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theoretical possibilities are made clear.

Importantly, the battery section covers AGM and lithium battery chemistries in detail, from safety through cost of operation. Lithium batteries have arrived in the marketplace and are covered in depth. There are many issues still to be solved. For example, the BMS (Battery Management System) that is included with lithium batteries has overcurrent protection, so great care must be taken to avoid a main power shutdown. Another issue is that temperature limitations can also cause the BMS to shut off. Ambient temperatures, either too high or too low, are serious issues with lithium batteries. Other differences include that optimum charging is not to full charge, but rather to about 90%.

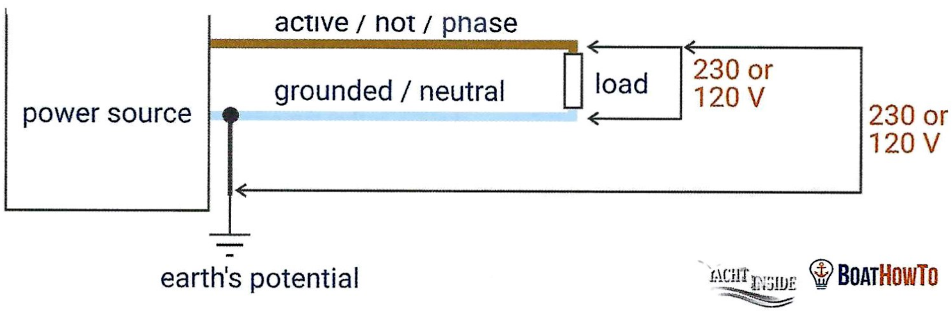
The cost of electricity generation is discussed in detail, including fuel, maintenance and equipment costs. By designing a system properly, equipment can be run efficiently and costs reduced. For example, using a 110 VAC belt-driven generator instead of a standalone generator saves on equipment costs and also allows the propulsion engine to operate closer to its peak efficiency RPM more of the time. The complex relationships between fuel economy, maintenance costs, charge rates, etc. are explained clearly. These topics may prove difficult for most boat owners. Vessel efficiency can only become more important in the foreseeable future.

Section 3: Networks and Technology Trends

The three subsections—NMEA 0183/2000, Digital Switching, and Electric Hybrid Propulsion—are new technology sections and have no video content yet. Some of this technology is experiencing rapid change and may well be short lived. Understanding how new technology can be harnessed is important. The old adage—just because you can do something doesn't mean you should—comes to mind. Not everything should be put on every network. Keep it simple; don't put unnecessary data on necessary displays. The modern MFD has so many display capabilities that there is a danger of it showing the wrong data at the wrong time!

AC Circuits

Alternating current circuits in their simplest form have a hot side (also known as the active, or phase, side) and a grounded side as in DC circuits, although the ground conductor (the rough equivalent of a DC system negative conductor) is known as the neutral. Instead of a battery, the source of power is a generator, either ashore or onboard, or sometimes a DC-to-AC inverter. There may be one or more transformers in the circuit.



The NMEA subsection covers the basics of data for NMEA 0183, NMEA 2000 and Ethernet and includes RS232 vs RS422, the physical layer of N2K, and OneNet. Descriptions are fairly technical and installation techniques are a little thin. I may be biased on this one because I teach it so often. The information about OneNet includes some fun facts and the descriptions are accurate for this new standard.

Digital switching—good & bad

Next is digital switching, which is mainly NMEA 2000 now. Digital switching has its place on boats. One interesting fact is that the overcurrent protection (OCP) devices are programmable. You can set the amp value of the circuits with software. This introduces the possibility of programming a low amp circuit with a high amp OCP device, possibly overloading the wire and causing a fire. The circuits can do more than just turn on and off; they can sense the current and log values. So, a bilge pump circuit can detect a sinking boat (long run time), a stiff and failing motor (increased amp draw), a dry bilge (decreased amp draw after pumping), a slow leak (too many cycles), etc.

The advantages of digital switching go far beyond saving on wiring costs and weight. One problem, though, is the chance for complete system failure because of the central control of the system. If the main brain dies, so does the system. The disadvantages of digital switching call for redundancy for mission critical systems. Having a parallel supply for the bilge pump, electronics and propulsion is a great idea on a vessel with digital switching. On boats, we need a "limp home" mode or bad will things happen.

Other problems surrounding digital switching include serviceability, support and obsolescence. Placing the Electric Control Modules (ECM) in remote parts of the boat to reduce wire lengths saves money but complicates servicing. The system also uses power to operate and, although minimal, can be parasitic. Another issue is that solid-state breakers, typically MOSFETs (Metal Oxide Semiconductor Field Effect Transistors), tend to react very quickly compared to standard breakers. This may cause it to trip improperly during turn-on inrush current. Obsolescence of systems has been a problem. These days, most use NMEA 2000, so the physical layer may work for a refit system. Still, digital switching is far from cross-brand compatible, so if a company exits the business, support can be a problem.

Electric propulsion

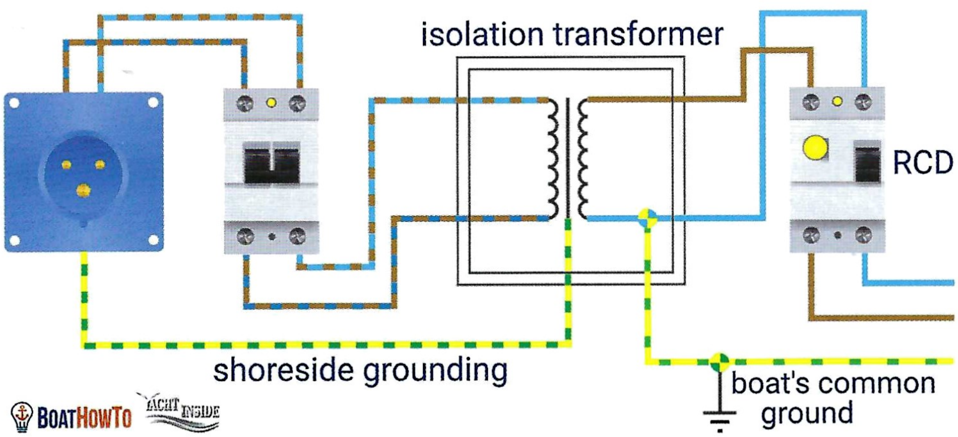
The final subsection in Section 3 is Electric Propulsion. As a technician, I have worked with many electric motors, from autopilot pumps to winches, bilge pumps and many others. Now that an electric motor is used for propulsion, the merging of the electrical and mechanical worlds is just about complete. We would all love to see boats go like cars. Tesla builds a good one and everyone follows. Unfortunately, on boats the power curve of the electric motor is very different than automotive. Making a long-range pure electric propulsion boat is far off. Short range, day sailing or short-haul ferries are feasible, but longer ranges will be elusive.

Range can be increased with a redundant fossil fuel engine. It can also be increased by charging the battery. Solar, wind, water current and fuel cells are discussed as "range extenders." Charts are shown for all-electric operation and switchover to hybrid (start generator to charge). This mode of operation is almost always less efficient than conventional propulsion. So, electric propulsion on boats is fine for short range but expensive

Boat Electrics 101

BoatHowTo's basic Boat Electric's 101 course consists of seven sections, each divided into lessons. The focus is on safety and fire prevention, Ohms Law, batteries, wiring diagrams, conductor selection and energy systems. Applications include power distribution, overcurrent protection, alternators and other chargers. The lessons teach the operator how equipment works and how to test and measure it, along with spotting an improper installation.

Much of the information is beyond what an installer or operator would require. I like this, though, because having a deeper understanding of the equipment and wiring on the boat can only help in resolving any issues that come up. Discussion of LED light spectrums is covered, which is interesting. RF interference and heat from LEDs are also covered, which is critical. Students learn why cheap LEDs fail early and about applications for LEDs, like navigation lights. The basic class is a good introduction to electricity on boats.



Isolation transformers have no physical connection between the shoreside ground and the ship's ground, eliminating it as a potential source of galvanic corrosion.

(Courtesy Yacht Inside, BoatHowTo)

and inefficient for normal boating. This is the so-called "serial hybrid" model, where an electric motor does the work and the generator makes the energy. In "parallel hybrids," the electric propulsion motor or the diesel motor drive the shaft.

With a parallel hybrid, the electric propulsion is used for low speeds and the diesel for higher speeds. When operating efficiencies are examined, using a generator to charge propulsion batteries is less efficient than a standard propulsion set-up. Since there are two sources of propulsion, the set-up is necessarily more complex. Of course, everything depends on vessel usage. Short trips under all-electric propulsion and recharging at the dock are typically extremely efficient. Onboard electrical generation presents many quandries related to efficiency, including curve of the motor, propeller and hull.

Other charging methods are also discussed. Solar and wind have obvious advantages in an electric boat. Another is regeneration. When a sailboat moves by wind, reverse torque is applied to the propeller. This can spin the electric motor backwards, making it a generator. Electric propulsion gets complicated. We must supply propulsion power and house power. Electric propulsion introduces a whole bunch of math and calculations into the scene: prop torque vs motor torque, resistive vs inductive loads, hull speeds vs prop sizing. Detailed discussions of many aspects of this emerging technology are included in the lesson. There are numerous ways to control a motor, numerous types of motors and many factors that are not obvious. Right now, the marketplace is in great flux. The best solutions are yet to come.

Overall, I give the BoatHowTo advanced course a grade of "A." These classes cover important safety topics for operators and provide a good overall understanding of technology on boats. Even though this class is written for end users/operators, I believe that engineers, installers, technicians and others can benefit from the broad information it presents. In my marine electronics niche, I may not need to know about generators, but I see them all the time and I use the power they generate. Understanding the systems that interact on a boat means better design, installation and troubleshooting. **MEJ**

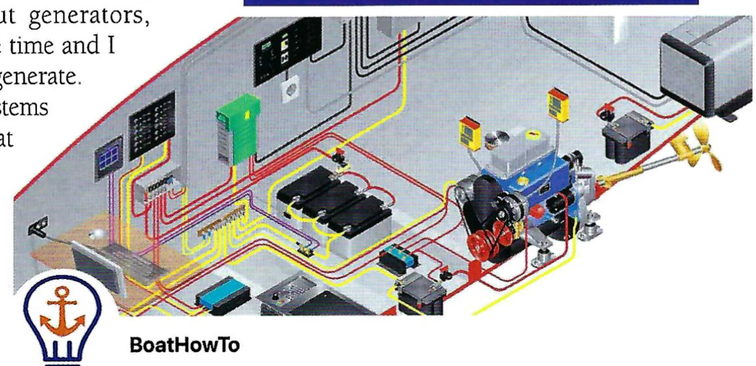
Seminars dive into electrical issues

OceanPlanet Energy, in collaboration with *Professional Boatbuilder* and *Ocean Navigator* magazines and *BoatHowTo.com*, is sponsoring a pair of intense two-day seminars focused on key electrical system issues aboard boats. The sessions will be held in Portland, ME, on April 17-18 and Oct. 29-30.

"Electrical systems are the leading cause of problems on boats that have more than a rudimentary electrical system. Most of these problems are preventable; they arise from a failure to abide by core design and installation principles," says Nigel Calder, who developed and will present the sessions. Calder is the author of *Boatowner's Mechanical and Electrical Manual* and co-creator of *BoatHowTo.com*. The plan, he says, is to "take a deep dive into both design and installation issues."

The seminar is grounded in the American Boat & Yacht Council (ABYC) standards for safe installations. But this is not an ABYC class, he says, because "You can have a safe installation that nevertheless functions poorly. We go beyond the standards to explain how to optimize performance."

For more information, go to seminar@oceanplanetenergy.com.



About the author

John Barry owns and operates Technical Marine Support in Pleasant Prairie, WI, and served on the NMEA Board of Directors for many years. He is a Certified Marine Electronics Technician, former Chairman of the NMEA Technical Committee and current Chair of the International Marine Electronics Alliance. He instructs all of the NMEA technical courses.