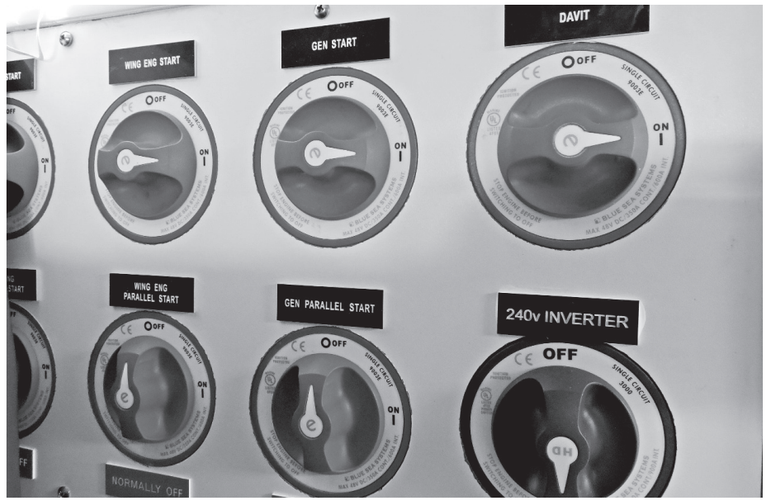
Electronics

BY JAMES HAMILTON

Power Flex

A Nordhavn owners's remote cruising habits inspire a generator overhaul.



Swapping out Dirona*'s ship's service selector switch allows the operator to feed the 240V breaker panel from either shorepower or the generator.*

A little over a year ago, we worked our way south from Fanning Island, Kiribati, towards Nuku Hiva in the Marquesas Islands. We were on a long, fuel-constrained run where we would cover 2,600 nautical miles without refueling. For most of the trip, we were heading up-current and into 30-knots of winds on the bow. The waves were fairly well-developed and spray filled the air day after day. The outside temperature was well over 80°, and the master stateroom was 88°, which made sleeping difficult. With the doors open for ventilation, a thin layer of airborne salt soon covered the interior. We were not crazy about closing the boat up and running the air conditioning, because that consumes more fuel and it was going to be a couple of weeks of generator run time at very low load.

As we neared Nuku Hiva, we concluded that we had far more fuel than we were going to use, so we might as well be comfortable and run the air conditioning. Typically I won't run the generator at under 20 percent load for long periods, but it'd live with it, and it was so wonderful and relaxing to finish the last few days of the crossing sleeping well, in air conditioned comfort. This trip convinced us we needed to find a way to air condition the boat underway without running the generator.

POWER NEEDS

In the Tuamotus, we were diving daily and loving it. It's remarkable to look up from 140 feet below and be able to clearly make out our dinghy floating above us, and then look the other way and see 150 feet down to the ocean floor and be surrounded by beautiful fish, sharks swimming by, and a sea turtle making a pass through the area. It was incredibly beautiful, but we found ourselves wondering what would happen if our generator failed. Without the generator, we can't fill SCUBA tanks, can't make water, and can't use the washer, dryer, or oven. The inability to make water when that far "out there" is not at all appealing. Our goal is to never have a trip end early, or be redirected by a fault, and it would be very difficult to get generator parts flown into some of the obscure, uninhabited islands we visited on this trip. We needed a backup to the generator, but really have no space for another generator aboard *Dirona*.

As we continued across the South Pacific we spent the vast majority of the time on anchor. But when we did go to a marina, the shorepower was rarely better than 15A. Some of those 15A connections could only reliably deliver 12A without triggering the breaker, and in some places the shorepower capacity was over-taxed by the visiting boats and consequently was sagging badly. Also, they were often 50-cycle connections and *Dirona* is a 60Hz boat, so we couldn't run most 240v appliances without running the generator.

We really felt we needed some way to draw what the shorepower had to offer, but to not trigger a breaker and not have to manage the boat to a consumption of less than 15A. Both Atlas and ASEA offer shorepower frequency converters that would handle the cycle difference, but they are expensive–friends have spent as much as $50,000 on shorepower conversions–and they still don't allow running the boat well at over 25A while drawing under 15A on the shorepower connection. The frequency converters didn't look like a good solution for the entire problem.

SHORT CIRCUIT

After many nights of thinking through options on passage, and planning and drawing up different solutions during the day, we came up with a solution that appears to solve all the problems outlined above. We installed the new design when we arrived in Whangarei, New Zealand, and, having used it for the last year, it really does seem to nail every requirement we hoped for, plus a few more.

If our generator fails, we need to be able to operate all 240V appliances including the watermaker and SCUBA compressor, and produce up to 8kW of power, without installing a second generator. This is essential were the main generator to fail and is also very useful for quick 240V loads like running the oven for 10 minutes without bothering to start the generator.

Light 240V loads, such as running a single HVAC while under way, is not an efficient use of the generator. While light loads generally aren't ideal, our bigger concern is that running the generator 24/7 increases the maintenance frequency. Changing the oil and filter every 10 days is not where we want to be.

We to be able to connect to 50Hz or 60Hz and run all appliances without restriction and not have to start the generator. We wanted the ability to run all appliances regardless of draw, without any restriction, without having to run the generator, and with only a single shorepower connection that might be as small as 10A at 240V, or 20A at 120V.

The author and his family enjoy cruising Dirona*, their Nordhavn 52, into remote cruising grounds, which inspired the Hamiltons to readdress their genset and its capacities.*

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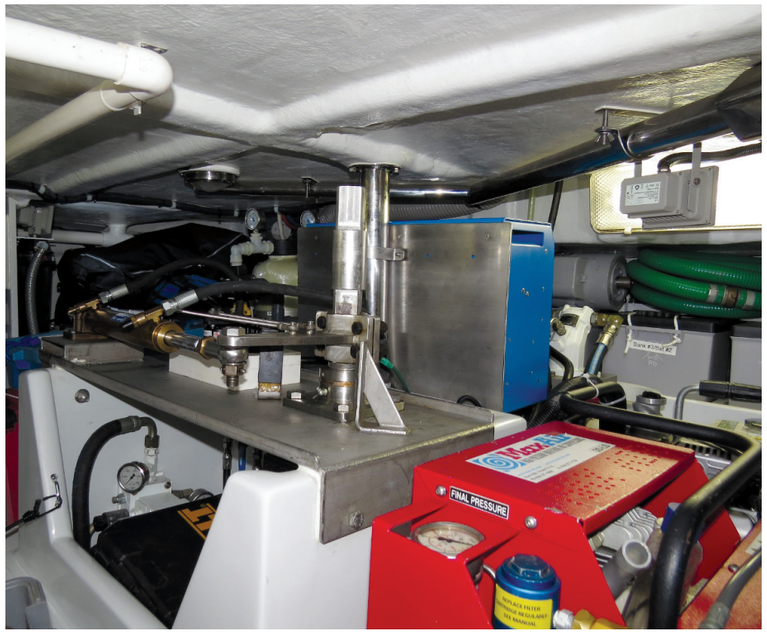


A look below reveals the extensive surgery needed to improve Dirona*'s genset.*

Boats are getting bigger and better equipped all the time and many marina shorepower systems are not up to the draw they are asked to deliver. It's not unusual to see shorepower voltage drop down 20 percent below nominal line voltages.

Voltage sags can damage equipment, so we needed isolation to ensure that our equipment gets clean, voltage-stable power even when the shore-side system is sagging under the collective load.

If the 110V inverter fails and we're not connected to 60Hz shorepower, we must start the generator to get 110V power. We also wanted a backup for a 110V inverter failure without plugging in or starting the generator.

Battery protection for shorepower loss: A big concern when leaving a

boat unattended at a marina is that the shorepower could get disconnected, unplugged, the breaker may trip, or a variety of other mishaps could leave the boat unpowered and drain the house batteries. This is bad for the batteries and might result in other problems such as spoiled freezer food. We want the system to ride through a shorepower fault by failing over to the generator, running it if needed to save the batteries, and returning automatically to shorepower if the genset came back.

POWER FIXES

I'll start with the equipment we installed and how the different components work together to solve the requirements we have itemized above.

The first step–and the most important part of the design–was to install a 240V, 60Hz inverter. This is the most important part of the design. Install a sufficiently large inverter system such that all appliances in the boat can be run off the inverter. On *Dirona*, we have a 4kW inverter to feed the 110V appliances, so 6kW is sufficient to support the 240V equipment we have on board. In our case, we installed two paralleled Victron 3kW, 110V inverters to achieve 6kW of 240V power. We particularly like this inverter choice because they are simple and don't include a charger–all they can do is invert–and are capable of delivering far more than their specification. The inverters are specified to deliver 6kW at 240V, which is roughly 25A, but they can deliver peak loads over 50A and can operate for extended periods at or even beyond their rated output without sag, over-temperature, or cutting out. They are tanks, and just keep delivering no matter what. I'm amazed to report they can start the SCUBA compressor, where the required inrush current at startup can exceed 50A.

After a year of use, we continue to love these units. The key to making this design work is to ensure that the inverter capacity is sufficient to run the boat without restriction, using whatever combination of 240V equipment you need.

So, if you choose to duplicate this design, ensure you have adequate inverter capacity. 6kW is enough for us but you can get 240V inverters in a variety of sizes up to 20kW. And if your boat is 60Hz, you'll need a 240V split-phase inverter–some appliances need that neutral connection.

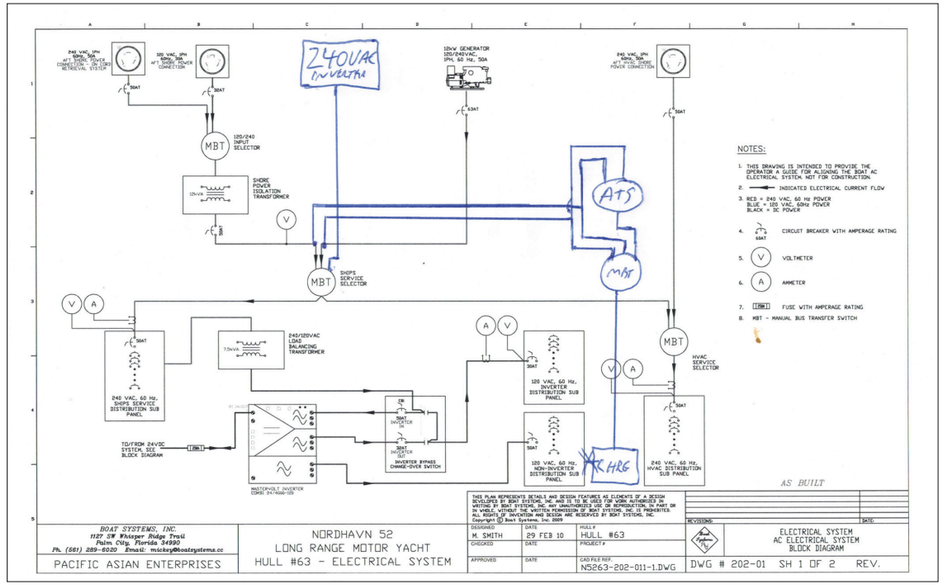
The next logical step was to replace the ship's service selector switch which, as delivered on *Dirona*, (leftmost of the three in the opening image) allows the operator to feed the 240V breaker panel from either shorepower or the generator. We replaced this new switch with one that adds support for a third input so we can feed the 240V panel and all 240V appliances on the boat from shorepower, generator, or inverter. This third position runs the entire house system off the new 240V inverter.

The third step is the switching. As delivered, the battery chargers on *Dirona* draw power from the 240V panel. In other words, one of the 240V "appliances" serves as the two battery chargers. It would be a very bad configuration to be running the 240V appliances off the inverter and have the battery chargers taking power from the inverter, using it to charge the batteries, which are then feeding the inverter. However, to support many of the use cases above, the chargers must be powered separately from the 240V panel. We want, for example, the 240V panel to be running off the inverter while the chargers are running off shorepower. So, we separated the battery chargers from the 240V panel and added a charger service switch to supply the chargers from either shorepower or the generator.

An electrical diagram showing these first three modifications is shown opposite.

The final component upgrade to complete the system was to replace the 85A start battery charger with a 190A at 24V alternator and installing heavier cabling for this larger alternator. The house battery bank already has a 190A at 24V alternator so, in this new configuration, we have two 190A at 24V alternators on the main engine. With the two alternators in aggregate, we have 9kW of power generation on the main engine. But, you probably wonder why we would ever want a 190A charger on the start battery system since the original 85A alternator was arguably already far more than would ever be required.

Well, it turns out that bigger is not really a problem in that a large alternator with a high quality smart regulator can produce whatever the start batteries need regardless of how low. So, having an extra-large alternator does no harm but is also



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unnecessary. When this second large alternator becomes very useful is when we parallel the house and start alternators onto the house battery bank. In that configuration, we can produce over 9kW of charging for the house battery bank. In our standard configuration, with only a single house battery bank alternator, we have 4.5kW of power available all the time. We can run air

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In addition to upgrading components, the owners replaced the existing cables with heavier-gauge wiring to ensure the system can handle the loads.

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conditioning units, the watermaker, and charge the batteries.

If we need more power, we can parallel in the start alternator and have 9kW available. This is useful if we have a generator failure, but there are times when it's nice to be able to charge the batteries at 300A and still be able to run the watermaker or air conditioning.

To make it easy to parallel in the start alternator when needed, we mounted a switch and warning light on the dash that closes a 200A continuous duty relay to make the second alternator available to supply the load when needed by just flipping a switch.

With these four sets of new components and changes installed, we can solve all the problems we outlined above by combining these components in different ways. Repeating the requirements list above, we'll see how each is solved.

ENERGY IN ACTION

Backup generator: The combination of the 6kW 240V inverter and the 9kW of main engine charging capability allows us to have a backup generator without giving up the space. Generators are reliable and we have never experienced a disabling fault, so it's hard to justify giving up the space for a second generator in a small boat. If we do end up needing the backup, the hours on our main will go up marginally, but the trip will be saved. It's nice to not give up space for a second generator and yet still have the redundancy protection that comes from one.

Efficient, light 240V loads: There are times when you'd like to run the oven for just 10 minutes, but it's just not worth starting the generator for such a short period. The 240V inverter is happy to deliver the power and although the battery draw is high, it's short enough that it doesn't really consume that much power. It's an efficient way to deliver the power for short periods without having to start the generator. Another usage model is low loads when under way. A single air conditioning unit draws less than 8A. It's not worth having the generator on 24/7 and having to change the oil every 10 days if you only need a small amount of power. The combination of the 6kW 240V inverter and the large on-engine alternators allows even fairly large 240V loads to be run any time without needing to start the generator.

The combination of installing a 240V inverter, upgraded ship's service selector switch, and a new charger service selector switch, allows the boat to be run entirely on the 60Hz inverter, while dual redundant 100A at 24V Mastervolt ChargeMaster 24/100s charge the batteries.

The Mastervolt chargers will run happily on either 50- or 60-cycle, so the batteries stay fully charged even on 50-cycle power while the boat continues to operate at full capability as a 60Hz system. We never need to start the generator to use the oven or laundry, for example. The combination of the chargers and the inverter can run any appliance at any time.

SHOREPOWER SHORTFALL

Very low amperage shorepower invariant: Extending on the 50Hz/60Hz invariant point above, we can run on shorepower connections as low as 10A at 240V or 15A at 110V even though our peak draw is often nearing 30A at 240V. Because the shorepower is charging the batteries and the inverter is powering the house, instead of needing the shorepower to provide the peak power requirements of the boat, we only need the average requirements. Often, for example, when a hair dryer is turned on and, say, the water heater is already on, the additional 8A draw will cause the shorepower breaker to disengage. This is because the shorepower is insufficient to meet the peak requirements of the boat.

If running using the battery charger and inverter pairing, as little as 10A is enough to power the boat even though our draws are often approaching 30A. Shorepower only needs to supply average

Installing a 240V inverter to power the ensures Dirona *does not have to deal with voltage sags due to the shorepower connection.*

power draws rather than peaks. It's amazing what a relief it is to not have to manage loads, worry about what is running when, and not have to go out and reset the breaker multiple times each day. Suddenly shorepower "just works." And there will be times when old shorepower breakers can't deliver their rated output. I've often seen 16A breakers that will pop at anything over 12A. That's fine too. We just set the charger draw to what is available onshore and forget about it, knowing we will take what we need but never more than the shorepower system can provide.

The 240V power systems in many U.S. and Canadian marinas is actually 208V. And, when overloaded, the "240" can sag down below 200V, which can damage electrical appliances. With the combination of a 240V inverter powering the house and only the battery chargers connected to shorepower, the boat always sees rock-solid 240V power through the inverter, while the battery chargers deal with voltage sags and other shorepower problems. The Mastervolt chargers will charge on just about any voltage and frequency in the world, so it all works without exposing the boat systems to sags, spikes and other shorepower related anomalies.

Our boat has both a 240V system and 110V system. The 110V system has a 4kW inverter and, if it fails, the only way to get 110V is to plug into 100V, 60Hz shorepower or start the generator. With the 240V inverter, we can still get 110V anytime without running the generator via the 240V inverter. It feeds single-phase 240V to the 240V system just as the generator would and the Nordhavn standard step down transformer will just keep producing nice, clean 110V output even if the 110V inverter fails.

You might ask why bother with the 110V inverter at all? It could be eliminated without giving up any advantage described here but a larger 240V inverter would be required if we gave up the 4kW of 110V inverter. If we were doing a new build today, we probably would opt for a larger 240V inverter and omit the 110V inverter entirely.

BATTERY PROTECTION

As mentioned before, our battery selector switch has three input options: shore, generator, and auto. Auto is an interesting configuration. In this mode, a large 120A continuously rated relay is used to select between shorepower and the generator. If shorepower is available, the battery chargers are run from the shorepower system. If the shorepower system fails, is unplugged, a breaker pops, or any other fault causes a loss of shorepower, then this relay switches the battery charger source to generator.

Since the generator is not running, you might wonder what value there is in switching to the generator. *Dirona* is equipped with generator auto-start, so, if the batteries are discharged to 50 percent capacity, the generator starts, the load is brought on after two-minute warm-up, it recharges the batteries, the load is removed for a one-minute cool-down, and then the generator shuts off again. The auto-start system is a simple extension of the Northern Lights Wavenet system.

The normal use of auto-start is to take care of the batteries and ensure they get charged when needed rather than when I remember. Jennifer and I are often late getting back to the boat after shore-side exploring. Rather than allow the batteries to discharge excessively, shortening their life, the generator just turns on and gets the job done without attention.

Auto-start is a personal decision where each owner needs to weigh the risk of running a generator without attention against the risk of allowing the batteries to discharge. Our take is well-maintained equipment works well and, just as most people wouldn't think twice of having their furnace kick on to prevent frozen pipes when they are not at home, we think auto-start is good for the boat. Even if you don't decide to install auto-start, the Northern Lights Wavenet system is strongly recommended. We love it.

The combination of the "auto" position on the charger selector switch with generator auto-start/stop means that if something goes wrong with the shorepower, the generator will start a day or so later, recharge the batteries, then shut down and wait until needed.

If the shorepower comes back, it switches back to shorepower and uses it again. We will also get email notification if the shorepower gets disconnected, and there are on-board alarms that signal this event, but it's still good to have backup to protect the nearly $8,000 worth of batteries. Even if we weren't cruising in 50Hz countries or remotely, where a generator failure would be a setback, we'd still install a 240V inverter. In fact, we've become so dependent on the system that we're considering getting a spare.

In the past, we needed to run the generator under way or at anchor to make water, do laundry, or for baking. We now only run the generator at anchor, either to charge the batteries, or for extended 240V loads. The 240V inverter and either shorepower or the main engine can handle the rest.

A shorepower connection anywhere in the world is now effectively the same as if we were in the U.S., with the added advantage of isolation from low or sagging supplies. And having air conditioning while under way in hot weather is wonderful. ■