**Indigo Lady Conversion to Solar/Electric, Design Specifications and Considerations**

**Primary Objective:** to have a catamaran for living aboard in the Caribbean that is solar powered and capable of island hopping without need for burning diesel fuel and without tending sails.

**Design Criteria:** Daytime cruising at 5 knots for 15-20 miles without the generator coming on. Continuous running capability for bad weather, longer runs or overnight passages by running one or both generators.

**Basic Plan:** Lots of solar panels, large shade roof, electric motors, diesel generators, LiFePO4 batteries, Inverters and 12 volt house batteries. 100% redundancy with a complete system in each hull, but with a cross-ship cable to allow transfer of power if needed.

**Components of the System**

**Boat:** Buy a used catamaran out of charter that has well-used sails, high engine hours and original rigging that should be replaced; this makes the boat more affordable for my purposes. Remove the mast, sails, diesels and saildrives and winches and sell them. In 2014 we found a 2002 Voyage 440 that had been in charter for 12 years. It was still currently in charter in the BVI and in great condition, we were able to buy her for $180,000.

**Roof:** The boat has a 25’ 1” beam so I planned a 20 feet wide, 32 feet long roof. I didn’t want the roof to act as an airfoil during hurricane winds so I designed a 12” wide air gap between the two roof halves, with a 20” wide walkway 6” above the gap. The walkway worked well for mounting a radar and antenna mast, and for working on the roof, cleaning the solar panels.

The roof starts forward of the salon windows, providing shade for the salon but also acting as a wind scoop when at anchor. The breeze blows over the cabin top and into the cockpit where we have two hammocks hanging from the roof frame and catching that breeze. The roof also extends out beyond the end of the sugarscoops, allowing room to hoist the dinghy. I mounted an electric winch for an ATV, and some swivel blocks for a 2:1 purchase when raising the dinghy. The dinghy comes all the way up to the roof to provide visibility under it while cruising. I have two wide nylon straps with turnbuckles that go under the dinghy to secure it in place and take the load off the winch.

The framework of the roof is all 2 1/8” diameter aluminum tube, designed and built in place, all welded construction, by a local firm that builds towers for sportfisher boats. There are four supports plus a ladder on each side, plus five centerline supports all attached to the deck or cabin roof. There are hand holds all around the perimeter of the roof frame. I did not design for water catchment as I planned on a watermaker.

The fiberglass panels for the roof are 32’ by 9 ½’ (built in 16’ pieces then joined) and the walkway is 32’ by 20”. All have three layers of fiberglass cloth, ¾” structural foam, three layers of fiberglass on top, all with epoxy then vacuum bagged. Strength and rigidity are excellent and weight is almost exactly one pound per square foot. The roof panels are secured to the framework with Plexus MA550 (shear strength 1200 psi, tensile strength 2000 psi). There is 123’ of bead length for adhesive force of over 1,000,000 pounds. I also used 16 bolts (5/16” St Stl), more for alignment while running adhesive bead, but they add additional strength. I positioned the roof panels in place, drilled holes for the bolts, lifted the panels up with small blocks of 2x4s, placed allthread in the bolt holes, ran the adhesive beads (only 20 minute working time!), pulled the 2x4 blocks out and tightened the allthreads, After curing, I replaced the allthreads with St Stl bolts.

I mounted the solar panels to the roof using fiberglass tabs. I bought 3” x 3” x ¼” G10 Fiberglass angle stock, then cut it into 1 ½” wide legs. Each solar panel has 6 legs (3 per side) with a bolt to the solar panel and Plexus MA550 adhesive to the roof. This worked very well. I secured the legs to the roof with a small screw to prevent sliding while the adhesive cured. The legs provided a 1 ½” air gap under the solar panels which aids in keeping the panel temperature down.

**Solar Panels:** I chose SunPower X22-360 solar panels. These are very high efficiency (22%) and a 360 watts each (60 volts rated, 70 volts max @ 6 amps rated, 6.5 amps max), and are very well built panels that will survive the marine environment. In the five years that they have been in service, their performance has been flawless. I chose Victron Blue Solar 150 volt 70 amp MPPTs. I wired two solar panels in series to get a maximum voltage of 140, then wired five pairs of panels in parallel to keep the max voltage at 140 and the max amperage to 32.5 amps. Each array has 10 solar panels, one array per side. The radar mast can provide some shading, but keeping the panels with 2 in series and five sets in parallel reduces any loss due to shading as only one pair would have reduced power, the others would supply full power. I did include a circuit breaker between the panels and the MPPT, I also have foil survival blankets (for our ditch bag) that can be used to blank any panels that need to be disconnected during the day. I have not had to do this, but it is easy insurance.

**Motors:** I chose Oceanvolt 15 KW electric motors with saildrives. The conversion factor for KW to HP is 0.745 KW = 1 HP, so 15 KW converts to 20 HP. My boat had two 40 HP Yanmar diesels so I was very skeptical about reducing the HP from 80 to 40!Everything I had read seemed to argue that because of the torque curve, the electric motors will provide performance similar to diesels at double the rating. I taught Physics and needed to be shown. Oceanvolt took two Voyage 440s (just like mine!) and put 15 KW motors in one, then shackled the electric boat back to back with a diesel boat and did a tug-of-war. The electric won easily with ½ of the “rated” power. I was still skeptical, but after five years of cruising, the performance of my two 15 KW electric motors really is about equivalent to the performance I had with the two 40 HP diesels. I will include my full performance curves and data at the end.

When I bought my units, the Oceanvolt saildrives were 4” shorter than the Volvo SD40s, and I needed to turn a similar sized prop. I had to cut down the motor mounts and create a new bed to mount the Oceanvolt saildrive and motor and get sufficient hull clearance for a vibration free prop to hull clearance. Oceanvolt has since changed their design length to be more easily exchanged with diesel saildrives. The electric motor uses a three-blade 16” diameter 11” pitch prop compared to a 17” diameter two-blade prop used by the diesels.

Since I bought my motors, Oceanvolt has added active cooling to both the motors and motor controllers. Mine have worked fine, but I did add two additional engine room blowers set on a thermostat to provide direct air cooling to both.

**Inverters:** I use Victron Quattro 5 KW inverters for running AC from the 48 VDC main battery banks. I almost never connect to shore power so these are on most of the time. AC systems don’t like having two competing sources for power, so I use an on/off/on selector switch to choose which Quattro (port or starboard) to activate.

**Sixth Year Critique:** After living on our boat for many month long periods over the last six years, here are some thoughts and critiques of the design.

* Bigger battery banks! My 12v 160AH batteries from Super B have not performed well and have reduced capacity. Their BMS is complex and expensive. My next improvement will be to replace the batteries with a bank that I build from 3.2v, 280 AH LiFePO4 cells from China. Building your own battery bank is not difficult (loads of YouTube info, some useful) and is ¼ to 1/10 the cost of buying commercially available battery systems. I am aiming for 57 KWH.
* Generator should be able to start and run without a connected battery bank, and the maximum output from the generators should not exceed the charging limit of the battery banks. Most of my generator/battery issues came from this conflict. Now the generators start from a 12v battery and can run the motors or inverter without a battery bank. If you are trolling on a sunny day and catch a fish, you stop the electric motors, but the generator and solar are then both charging the battery bank and you don’t want to over-amp the batteries.
* The roof is Awesome! Great shade, solar panels are secure, dinghy hangs well, and our hammocks are in the shade and breeze.
* Have a cross-ship cable (positive and negative) so one generator can run both motors or charge either battery bank (one at a time; the BMSs don’t like being connected). Running one generator while running both motors at 5-6 KW each is very efficient; 5 knots at .7 GPH. Slightly faster cruising at 7 KW per motor, still one generator, and getting 5 ½ to 6 knots into small chop and 10 knot wind.
* Oceanvolt motors are excellent. No problems in six years. They originally falsely reported high temperatures but a software change eliminated the false overtemperature shutdowns and there have been no temperature issues since. Oceanvolt has gone to more active cooling of both the motors and the controllers.
* Victron equipment has worked well. The CCGX system controllers are easy to use and access all of the system settings. The MPPT solar controllers can be monitored by Bluetooth and can be easily reprogrammed if batteries need a modified charging algorithm. The Quattro inverter chargers have worked well.
* My ProMariner battery charger takes 110 VAC from the inverter and charges the 12 VDC house batteries (golfcart batteries, 6 volt 105 amphour). This works well and eliminates the potential electronic noise of a DC to DC transformer to charge house batteries from the main 48 VDC banks.
* At anchor for a few days, being electricity rich is nice. Water maker, ice maker, bread machine, microwave with convection oven, waffle iron, water heater, electric tea kettle, coffee maker, refrigerator, freezer, all of our computer and other electronic communications, TV, …

Why aren’t more people doing this? There are lots of catamarans coming out of charter with standing rigging needing replacement, tired sails and diesels with high hours. Buy them cheaply, sell the mast and diesels, then build your boat.