Flexible Solar Panels for Beneteau Oceanis 40

I bought 3 75W flexible solar panels from China to mount over the bimini top of my Beneteau Oceanis 40.

Model	Power (W)	Size (mm)	Voc(V)	Isc(A)	Vmp(V)	Imp(A)	Cell effciency	Net Weight
SYFD-F SPC18W	18W	434*277*3mm	23.7V	1.03A	19.4V	0.93A	20.5%	0.29KG
SYFD-F SPC25W	25W	555*277*3mm	21.6V	1.54A	17.6V	1.42A	21.5%	0.37KG
SYFD-F SPC-30W	30W	515*415*3mm	21.4V	1.92A	17.5V	1.71A	19.6%	0.49KG
SYFD-F SPC40W	40W	535*415*3mm	23.6V	2.05A	19.5V	2.33A	22.2%	0.60KG
SYFD-F SPC50W	50W	545*535*3mm	21.6V	3.05A	17.6V	2.84A	21.5%	0.70KG
SYFD-F SPC60W	60W	734*535*3mm	20.12V	4.02A	16.6V	3.59A	19.6%	0.91KG
SYFD-F SPC75W	75W	820*535*3mm	23.94V	4.10A	19.4V	3.80A	20.1%	0.98KG
SYFD-F SPC80W	80W	992*540*3mm	18.80V	5.61A	15.4V	5.19A	18.8%	1.20KG
SYFD-F SPC85W	85W	1050*550*3mm	20.20V	5.60A	16.9V	5.04A	18.6%	1.38KG
SYFD-F SPC90W	90W	1050*540*3mm	20.70V	5.70A	17.1V	5.26A	19.0%	1.35KG
SYFD-F SPC95W	95W	1050*540*3mm	20.90V	5.89A	17.4V	5.46A	20.2%	1.35KG
SYFD-F SPC100W	100W	1050*540*3mm	21.20V	6.10A	17.7V	5.70A	21.3%	1.35KG
SYFD-FSPC110W	110W	1175*540*3mm	23.50V	6.02A	19.55V	5.63A	19.9%	1.55KG
SYFD-F SPC120W	120W	1430*540*3mm	20.50V	8.01A	16.80V	7.15A	19.2%	1.62KG
SYFD-F SPC130W	130W	1430*540*3mm	21.00V	8.26A	17.00V	7.64A	20.1%	1.62KG
SYFD-F SPC135W	135W	1082*796*3mm	24.30V	7.23A	19.90V	6.78A	19.0%	1.66KG
SYFD-F SPC140W	140W	1082*796*3mm	24.50V	7.56A	20.00V	7.08A	19.5%	1.66KG
SYFD-SPC180W-1	180W	1302*796*3mm	39.80V	5.85A	32.92V	5.48A	20.0%	2.0KG
SYFD-SPC180W-2	180W	1302*796*3mm	20.30V	11.57A	16.80V	10.71A	20.0%	2.0KG

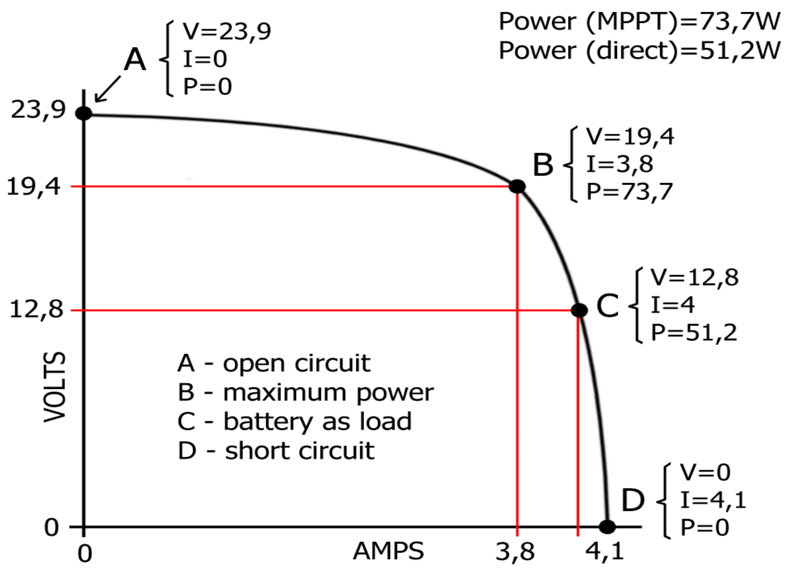
I could use the original canvas to support the panels, but it was slightly worn. So, I bought 7m acrylic fabric and made a new canvas using the old one as a master. For this work I used my old Singer sewing machine. I am not an expert in sewing, but I'm very surprised with the

quality of the final work. I bought a MPPT controller capable of supporting 3 panels connected in series. I had to bought 2 new stainless steel tube bases because the originals ones were of the

articulated type and they do not allowed the entry of electrical wires inside the tube. With the new bases, there are no holes in the deck for the cable entry. The MPPT controller is TR-2210RN.

I used three panels in series. They can produce a maximum voltage (see the table in the other post) 3 x 23.94 = 71.82 volts. Most MPPT regulators do not admit such a high voltage input. Fortunately the TR-2210RN regulator allows an input voltage of 100 volts. By connecting panels in series the current is smaller than it would be if they were in parallel and the section of electrical cable connecting the panels to the controller may be smaller. In my case I used a section of 4mm2. The distance of the panels to the batteries is about 7 meters. So I have a total cable length of 14 meters. The section of the cable is critical, since the voltage drop along the cable will be responsible for a loss of power. If the panels were connected in parallel we could use a MPPT controller with a lower input voltage (less expensive). In that case, the current would be 3 times higher and, for the same loss of power, I would need to increase the cable size from 4mm2 to 12mm2. That would be more expensive and, moreover, would make the job of inserting the cable through the 1 inch stainless steel tube into a very difficult task. The controller cable to the batteries carries a larger current, but it is very short. I used a cable with a 10mm2 section. The positive cable has a 30A fuse (also seen in on of the pictures), near the battery.

I really think that my choice of a serial connection is fine. I leave here my reasoning and I hope I am not mistaken in my calculations. I hope this post will be useful to clarify some aspects of solar panel wiring. I will use 2 photos to illustrate my point. In the first picture I show the I-V curve for the 75W solar panel. I point out 4 possible operating points along the curve. Point A is the point of



operation when there is no load connected to the panel (open circuit). The electric current will be zero and the voltage 23.9 V. Obviously, the power to the load is zero. Point B refers to the case of an electronic device (MPPT controller) as a load to the solar panel. The voltage is 19.4 V, the current is 3.8 A and the power supplied to the controller is 73.7 W. Point C is the operating point if we connect the panel directly to the battery (or if you use a non-MPPT controller). The voltage supplied by the panel will be imposed by the battery and assuming a normal battery voltage of 12.8 V. Using the curve I believe that the current is about 4 A, which means that the power supplied by the panel is 51.2 W. These two numbers, 73.7 and 51.2 show the improvement when using the MPPT controller.

Before comparing the wiring series parallel wiring, let me consider the cable connecting the panels to the controller. In my case the distance between the panels and the controller is about 7 meters long. I used a photovoltaic cable with a cross section of 4mm2. This is a very flexible cable, well protected from the environment, and with a total outer diameter of 6 mm. If we evaluate the ohmic resistance of a copper wire with a length of 14 m and a section of 4 mm2 we will get 60 mili-ohms. I will use this value to estimate the power loss along this critical cable. Later I will discuss the effect of shading on the panels and I will disagree with the opinion that parallel wiring offers significant advantages over the serial wiring.

Taking all of the three panels as a single identity (... Thevenin ...) the I-V curve of the set is very similar to that of the first image in the case of a single panel. We only need to change the numbers as labels. Assuming that the panels are used with an MPPT controller, I only comment about point B (the point of maximum power transfer). In the parallel case, the output voltage would be 19.4 V, but the output current would be 11.4 A. In the series case, the output voltage would be 58.2 V and

Parallel	B	V=19,4	R=0,06	
		I=11,4	ΔV=0,68	Loss=3,5%
		P=221	ΔW=7,8	

Series	B	V=58,2	R=0,06	
		I=3,8	ΔV=0,23	Loss=0,4%
		P=221	ΔW=0,87	

the output current would remain 3.8 A. Note that, in the case of series wiring, the MPPT controller must support an input voltage of about 60 V. Not all controllers on the market support this "superior" voltage.

The voltage drop across resistor R cable to carry a current I is R x I. In the case of the parallel connection (L = 11.4 A) the voltage drop is about 0.68 V. Since the voltage available at the panel is 19.4 V, the voltage drop means a loss of power of 3.5%. In Watts, the power loss is 7.8 W. For the series connection, the voltage drop is 0.23 V. However, the voltage available on the panel is 58.2 V, which means a loss of 0.4% or 0.87 W in terms of watts. Finally, in addition to lower power loss, the serial connection provides a nice clean way to connect the panels, as you can see in my initial images.

Following is my view of shading on solar panels. I will assume a panel with 30 cells capable of supplying the 12V 5A. I am going to refer to 3 images. In Fig.1.A, I represent the panel in normal operation. There are zone protection shunt diodes (bypass diodes), as shown in the image. The diodes are reverse biased and do not consume any power. Suppose now that the panel is shaded.

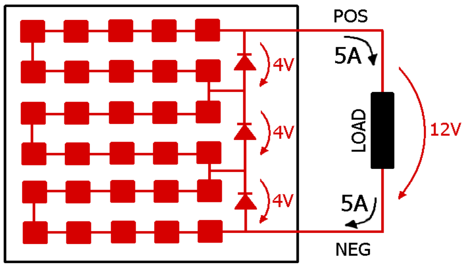


Fig 1.A

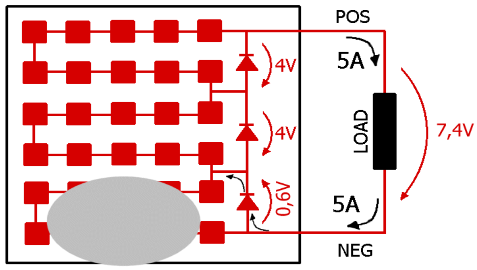


Fig 1.B

The situation is illustrated in Fig.1.B. The shaded cells can be considered as open circuits. The panel continues to operate but with a lower output voltage of 7.4 V in this case. If this panel is connected in series with other panels, there will be no problem. By contrast, we do not want to connect this panel in parallel with other 12V panels. In Fig.2, I represent the mounting of the

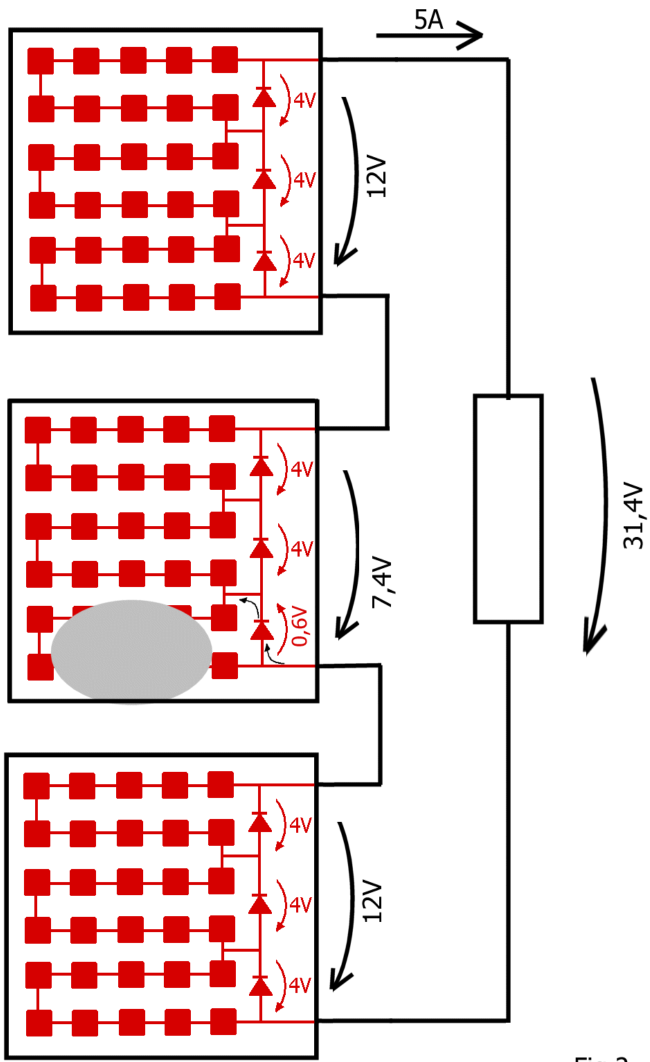


Fig 2

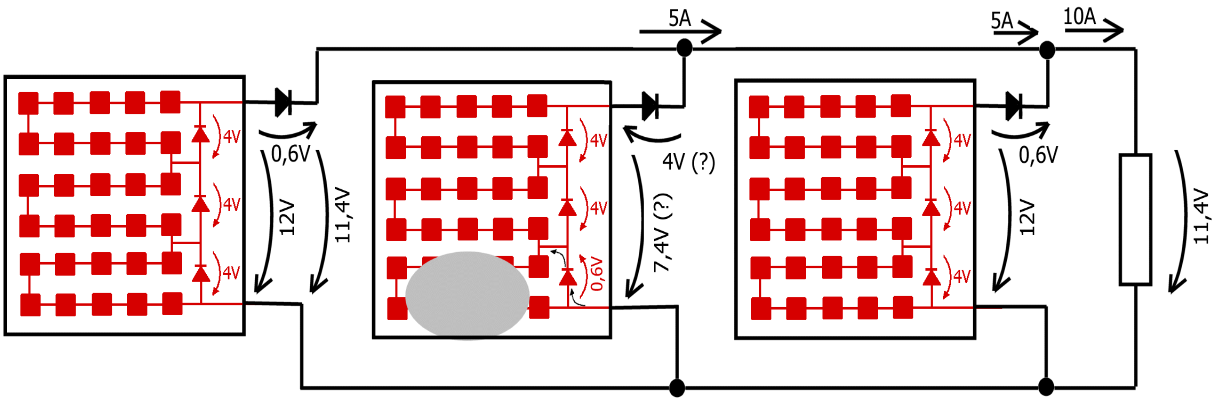


Fig 3

panels in series. One panel is shaded, so that the total output voltage is 31.4 V instead of 36V. In Fig.3, I represent what I would use if I had to connect the panels in parallel. I'm not entirely sure if I'm correct. First, I would use 3 external diodes. Electrical engineers do not like voltage sources connected in parallel. By contrast, the current sources should be connected in parallel. The question is: should we consider the panel as a voltage or current source? or as a "mixed" source? I will not try to answer. External diodes consume 3 W power which is not good. And the shading panel is completely off. It does not contribute to any current to the load. Instead we will have 10A 15A load like if only 2 panels.