Solar Power for Emergency Communications

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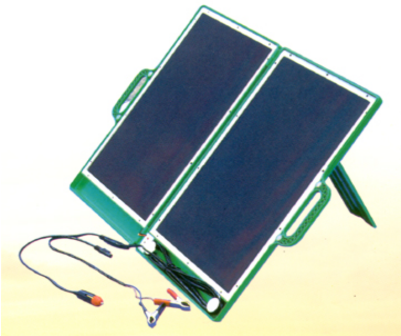


Introduction

When there is not any electrical power or fuel for an emergency generator, solar (photovoltaic) power is the next best thing. When a solar cell is exposed to light, electron-hole pairs are generated proportional to the intensity of the light. Solar cells are made by bonding p-type and n-type semiconductors. The negatively charged holes move to the p-type semiconductor. They collect at both electrodes to form a potential. When two electrodes are connected to a load, current flows. Amorphous silicon cells have a narrow sensitivity to the visual light spectrum, usually in the infrared region and operate at an efficiency of about 15%. Various configurations of solar cells are being researched such as, multi-junction solar cells. Multi-junction solar cells use several layers of semiconductors. Each layer is sensitive to a specific region of the visual light spectrum, thereby increasing the efficiency of the solar cell conversion to electricity. Multi-junction solar cells are not currently available commercially because the cost is prohibitive. Typically, solar cells have a life expectancy of 40 years.

Two photovoltaic solar panel systems have been evaluated for emergency communications. One is low power, small, lightweight and portable. The other is higher power, heavier, and requires assembly. The "Briefcase" 13 watt solar panel is portable, measuring 20.07" x 14.76" x 1.57", and weighing 12 pounds. The 3 panel 45 watt solar panel is not portable, measuring 36.34" x 36.96", and weighing about 40 pounds. The 3 panel system requires assembly.

Typically solar cells measuring 2 inches by 0.5 inches produce 0.45 volts at 100 milliamps, or 45 milliwatts per square inch. The power generated by the "Briefcase" solar panel is calculated as 296.23 square inches x 45 milliwatts per square inch = 13.3 watts.

Solar Panels don't usually produce enough current to power most devices. Therefore, solar panels are usually used to charge batteries. During daylight, the transceiver draws power from the battery, which is being charged by the solar panel. During nighttime, the transceiver draws power from the battery even though it is not being charged. For 24 hour operation two solar panels and two batteries will be needed. The second solar panel can be used to charge the second battery for use at night. Typically discharging a battery below 50% of its charge will probably damage the battery. Charging 50% of the same battery will require a charge for half the time.

Power Requirements

The following power supply currents were measured for the Yaesu FT-8900R 29/50/144/430 MHz FM Transceiver while in the 144 MHz FM mode:

Transceiver Mode	Transceiver Current	Watts	50% Battery Runtime (7ah/2=3.5 ah)
Receive	0.27 amps	3.24	12.95 hours
5 Watts Output	2.15 amps	25.8	1.63 hours
10 Watts Output	2.86 amps	34.32	1.23 hours
20 Watts Output	4.01 amps	48.12	0.875 hours (59 minutes)
50 Watts Output	7.42 amps	89.04	0.47 hours (28 minutes)

7 Amp Hour Battery for Lightweight Quick Setup Operation

A Power Sonic PS-1270, 12 volt 7 ah, 5.7 pounds, sealed lead acid battery with F1 terminals was used. The 12 volt 7 amp hour battery will require a full charge of 12 volts 7 amps for 1 hour or 12 volts 0.5 amps for 14 hours. Typically discharging a battery below 50% of its charge will probably damage the battery. Charging 50% of the same battery will require a charge for half the time. In this case, it will take 7 hours to charge the battery from 50% to 100% at a charging rate of 0.5 amps. Therefore, a fully charged 12 volt 7 amp hour battery can be used to supply 3.5 amp hours or less and can be recharged in 7 hours. Seven hours of useable daylight is about the most that can be expected in New York.

Amp Hours = Amps x Hours, Watt Hours = Watts x Hours

The 12 volt 18 ah battery will deliver 9 amp hours (50% capacity) of current.

The formula for calculating battery capacity is:
Battery Capacity (hours) = Battery Amp Hour / Current

When using the Yaesu FT-8900 in receive mode only, the battery will deliver current for 33.33 hours (9 amp hours / 0.27 amps).

If the Yaesu FT-8900 (output of 20 watts) is used in transmit mode for 0.87 hours (52 minutes), it will have used the entire 50% battery capacity of 3.5 amp hours without any current remaining for receive. (0.87 hours = 3.5 amp hours / 4.01 amps)

If the Yaesu FT-8900R (output of 20 watts) is used in transmit mode for 1/2 hour, it will have used 4.01 amps for 1/2 hour or 2.0 amp hours (4.01 amps x 1/2 hour). The remaining 1.5 amp hours will allow the radio to operate in receive mode for 5.55 hours (1.49 amp hours / 0.27 amps).

The Yaesu FT-8900R (output of 20 watts) power consumption and estimated time for 50% of the 7 ah battery (3.5 ah) capacity is:

Current while Transmitting = Transceiver Current (in transmit mode) x hours
Current while Receiving = 50% battery capacity – Current while Transmitting
Receive time = Current while Receiving / Transceiver Current (in receive mode)

<u>Calculating Receive Time:</u>

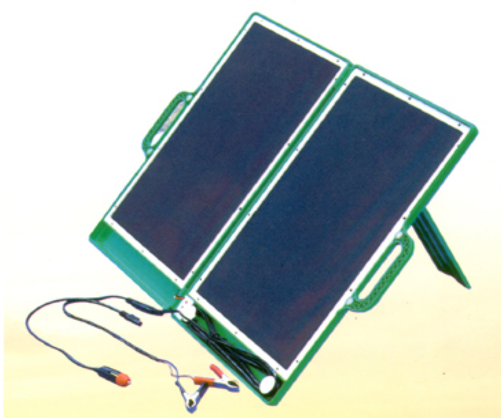
$$\text{Receive Time} = \frac{\text{50\% battery capacity} - (\text{Transceiver Current (in transmit mode) x hours})}{\text{Current while receiving}}$$

<u>Calculating Receive Time for the Yaesu FT-8900 (20 watt output) with 7 ah Battery:</u>

$$\text{Receive Time} = \frac{\text{3.5 ah} - (\text{4.01 amps x hours})}{\text{0.27 amps}}$$

Transmit Time	Current while Transmitting	Current while Receiving	Receive Time
0.87 hour (52 min)	3.5 amps	0	0 min
0.5 hours (30 min)	2.00 amps	1.5 amps	5.56 hours
0.25 hours (15 min)	1.00 amps	2.5 amps	9.26 hours
0.125 hours (7.5 min)	0.50 amps	3 amps	11.1 hours

7 Amp Hour Battery and 13 Watt Solar Panel for Lightweight Quick Setup Operation



<u>"Briefcase" Solar Panel Specifications:</u>
Amorphous silicon solar cells
Power: 13 Watts maximum
Working voltage: equal or greater than 14 v
Working current: equal or greater than 750 ma
Dimension and Weight: 20.07" x 14.76" x 1.57", 12 pounds

On a bright sunny April day, 70 degrees F., in Northport, New York, it produced 0.5 amps at 13 volts (6.5 watts) into a 12 volt 7 ah battery with a transceiver connected to the battery. The amount of solar panel power output depends upon the intensity of the sun. To calculate the solar panel output energy produced, 1 watt = 1 joule per second. 6.5 watts = 6.5 joules per second of energy output.

Typically solar cells measuring 2 inches by 0.5 inches produce 0.45 volts at 100 milliamps, or 45 milliwatts per square inch. The power generated by the "Briefcase" solar panel is calculated as 296.23 square inches x 45 milliwatts per square inch = 13.3 watts.

With a solar panel and battery system, drawing less current than the solar panel output will result in surplus current to charge the battery. Drawing more current than the solar panel output will result in drawing current from the battery.

The 12 volt 7 ah battery will deliver 3.5 amp hours of current (50% capacity). The solar panel will deliver (sunny day in New York) 0.5 amp hours of current. The total output of the battery (50% capacity) and solar panel will be 4 amp hours.

When using the Yaesu FT-8900 in receive mode only, the battery while connected to the solar panel will deliver current for 14.8 hours (4 amp hours / 0.27 amps).

If the Yaesu FT-8900 (output of 20 watts) is used in transmit mode for 1 hour, it will have used the entire 50% battery plus solar panel capacity of 4 amp hours without any current remaining for receive. (1 hour = 4 amp hours / 4.01 amps).

If the Yaesu FT-8900R (output of 20 watts) is used in transmit mode for 1/2 hour, it will have used 4.01 amps for 1/2 hour or 2.0 amp hours (4.01 amps x 1/2 hour). The remaining 2.0 amp hours will allow the radio to operate in receive mode for 7.41 hours (2.0 amp hours / 0.27 amps).

The Yaesu FT-8900R (output of 20 watts) power consumption and estimated time for 50% of the 7 ah battery (3.5 ah) capacity plus solar panel output (3.5 amp hours + 0.5 amp hours) is:

Current while Transmitting = Transceiver Current (in transmit mode) x hours
Current while Receiving = 50% battery capacity plus solar current – Current while Transmitting
Receive time = Current while Receiving / Transceiver Current (in receive mode)

<u>Calculating Receive Time:</u>

$$\text{Receive time} = \frac{(50\% \text{ battery capacity} + \text{Solar}) - (\text{Transceiver Current (in transmit mode) x hours})}{\text{Current while receiving}}$$

<u>Calculating Receive Time for the Yaesu FT-8900 (20 watt output) with 7 ah Battery + 13 w Solar:</u>

$$\text{Receive time} = \frac{4 \text{ ah} - (4.01 \text{ amps x hours})}{0.27 \text{ amps}}$$

Transmit Time	Current while Transmitting	Current while Receiving	Receive Time
1 hour (60 min)	4.01 amps	0	0 min
0.5 hours (30 min)	2.00 amps	2.00 amps	7.41 hours
0.25 hours (15 min)	1.00 amps	3.00 amps	11.11 hours
0.125 hours (7.5 min)	0.50 amps	3.5 amps	12.96 hours

18 Amp Hour Battery for Higher Power Operation

A Power Sonic PS-12180 NB, 12 volt 18 ah, 12.6 pounds, sealed lead acid battery with nut and bolt terminals was used. The 12 volt 18 amp hour battery will require a full charge of 12 volts 18 amps for 1 hour or 12 volts 2.73 amps for 6.59 hours. Typically discharging a battery below 50% of its charge will probably damage the battery. Charging 50% of the same battery will require a charge for half the time. In this case, it will take 6.59 hours to charge the battery from 50% to 100% at a charging rate of 2.73 amps. Therefore, a fully charged 12 volt 18 amp hour battery can be used to supply 9 amp hours or less and can be recharged in 6.59 hours. Seven hours of useable daylight is about the most that can be expected in New York.

Amp Hours = Amps x Hours, Watt Hours = Watts x Hours

The 12 volt 18 ah battery will deliver 9 amp hours (50% capacity) of current.

The formula for calculating battery capacity is:
Battery Capacity (hours) = Battery Amp Hour / Current

When using the Yaesu FT-8900 in receive mode only, the battery will deliver current for 33.33 hours (9 amp hours / 0.27 amps).

If the Yaesu FT-8900R (output of 20 watts) is used in transmit mode for 2 hours, it will have used 4.01 amps for 2 hours or 8.02 amp hours (4.01 amps x 2 hours). The remaining 0.98 amp hours will allow the radio to operate in receive mode for 3.63 hours (0.98 amp hours / 0.27 amps).

If the Yaesu FT-8900R (output of 20 watts) is used in transmit mode for 1 hour, it will have used 4.01 amps for 1 hour or 4.01 amp hours (4.01 amps x 1 hour). The remaining 4.99 amp hours will allow the radio to operate in receive mode for 18.48 hours (4.99 amp hours / 0.27 amps).

The Yaesu FT-8900R (output of 20 watts) power consumption and estimated time for 50% of the 18 ah battery (9 ah) capacity is:

Current while Transmitting = Transceiver Current (in transmit mode) x hours
Current while Receiving = 50% battery capacity – Current while Transmitting
Receive time = Current while Receiving / Transceiver Current (in receive mode)

Calculating Receive Time:

$$\text{Receive Time} = \frac{\text{50\% battery capacity – (Transceiver Current (in transmit mode) x hours)}}{\text{Current while receiving}}$$

Calculating Receive Time for the Yaesu FT-8900 (20 watt output) with 18 ah Battery:

$$\text{Receive Time} = \frac{\text{9 ah} - \text{(4.01 amps x hours)}}{\text{0.27 amps}}$$

Transmit Time	Current while Transmitting	Current while Receiving	Receive Time
2 hours	8.02 amps	0.98 amps	3.63 hours
1 hour	4.01 amps	4.99 amps	18.48 hours
0.5 hours (30 min)	2.00 amps	7 amps	25.93 hours
0.25 hours (15 min)	1.00 amps	8 amps	29.63 hours
0.125 hours (7.5 min)	0.50 amps	8.5 amps	31.48 hours

18 Amp Hour Battery and 45 Watt Solar Panel for Higher Power Operation

45 Watt Solar Panel System Specifications:
3 pieces Amorphous silicon solar cells panel (36.34" x 12.32" x 0.75") each
3 x 447.71 square inches = 1,343.13 square inches total
Maximum current, 3000 ma
Power: 15 watts max per panel
Peak voltage: 23.57 volts open current
Weight: 9.7 pounds each panel without the frame (about 40 pounds total)
Charge regulator for 12V, 9V, 6V, 3V outputs, and over charge / discharge / load protection

Typically solar cells measuring 2 inches by 0.5 inches produce 0.45 volts at 100 milliamps, or 45 milliwatts per square inch. The power generated by the 45 watt solar panel system is calculated as 1,343.13 square inches x 45 milliwatts per square inch = 60.44 watts.

A Power Sonic PS-12180 NB, 12 volt 18 ah, 12.6 pounds, sealed lead acid battery with nut and bolt terminals was used.

On a sunny April day, 61 degrees F., in Northport, New York, it produced 2.73 amps at 13.18 volts (35.98 watts) into a 12 volt 18 ah battery with a transceiver connected to the battery. The unloaded voltage measured was 22.68 volts directly from the 3 solar panels connected in parallel. The amount of solar panel power output depends upon the intensity of the sun. To calculate the solar panel output energy produced, 1 watt = 1 joule per second. 35.98 watts = 35.98 joules per second of energy output.

The 12 volt 18 ah battery will deliver 9 amp hours of current (50% capacity). The solar panel will deliver (sunny day in New York) 2.73 amps of current. The total output of the battery (50% capacity) and solar panel will be 11.73 amp hours.

When using the Yaesu FT-8900 in receive mode only, the battery while connected to the solar panel will deliver current for 43.44 hours (11.73 amp hours / 0.27 amps).

If the Yaesu FT-8900 (output of 20 watts) is used in transmit mode for 2 hours, it will have used the 8.02 amps for 2 hours. The remaining 3.71 amp hours will allow the radio to operate in receive mode for 13.74 hours (3.71 amp hours / 0.27 amps).

If the Yaesu FT-8900R (output of 20 watts) is used in transmit mode for 1 hour, it will have used 4.01 amps for 1 hour. The remaining 7.0 amp hours will allow the radio to operate in receive mode for 28.59 hours (7.72 amp hours / 0.27 amps).

The Yaesu FT-8900R (output of 20 watts) power consumption and estimated time for 50% of the 18 ah battery (9 ah) capacity plus solar panel output (9 amp hours + 2.73 amp hours) is:

Current while Transmitting = Transceiver Current (in transmit mode) x hours
Current while Receiving = 50% battery capacity plus solar current – Current while Transmitting
Receive time = Current while Receiving / Transceiver Current (in receive mode)

<u>Calculating Receive Time:</u>

$$\text{Receive time} = \frac{\text{(50\% battery capacity + Solar) – (Transceiver Current (in transmit mode) x hours)}}{\text{Current while receiving}}$$

<u>Calculating Receive Time for the Yaesu FT-8900 (20 watt output) with 18 ah Battery + 45 w Solar:</u>

$$\text{Receive time} = \frac{\text{11.73 ah – (4.01 amps x hours)}}{\text{0.27 amps}}$$

Transmit Time	Current while Transmitting	Current while Receiving	Receive Time
2 hours (120 min)	8.02 amps	3.71 amps	13.74 hours
1 hour (60 min)	4.01 amps	7.72 amps	28.59 hours
0.5 hours (30 min)	2.00 amps	9.73 amps	36.04 hours
0.25 hours (15 min)	1.00 amps	10.73 amps	39.74 hours
0.125 hours (7.5 min)	0.50 amps	11.23 amps	41.59 hours

Summary

Calculating Receive Time for the Yaesu FT-8900 (20 watt output) with 7 ah Battery:
(5.7 pounds)

Transmit Time	Current while Transmitting	Current while Receiving	Receive Time
0.87 hour (52 min)	3.5 amps	0	0 min
0.5 hours (30 min)	2.00 amps	1.5 amps	5.56 hours
0.25 hours (15 min)	1.00 amps	2.5 amps	9.26 hours
0.125 hours (7.5 min)	0.50 amps	3 amps	11.1 hours

Calculating Receive Time for the Yaesu FT-8900 (20 watt output) with 7 ah Battery + 13 w Solar:
(17.7 pounds)

Transmit Time	Current while Transmitting	Current while Receiving	Receive Time
1 hour (60 min)	4.01 amps	0	0 min
0.5 hours (30 min)	2.00 amps	2.00 amps	7.41 hours
0.25 hours (15 min)	1.00 amps	3.00 amps	11.11 hours
0.125 hours (7.5 min)	0.50 amps	3.5 amps	12.96 hours

Calculating Receive Time for the Yaesu FT-8900 (20 watt output) with 18 ah Battery:
(12.6 pounds)

Transmit Time	Current while Transmitting	Current while Receiving	Receive Time
2 hours	8.02 amps	0.98 amps	3.63 hours
1 hour	4.01 amps	4.99 amps	18.48 hours
0.5 hours (30 min)	2.00 amps	7 amps	25.93 hours
0.25 hours (15 min)	1.00 amps	8 amps	29.63 hours
0.125 hours (7.5 min)	0.50 amps	8.5 amps	31.48 hours

Calculating Receive Time for the Yaesu FT-8900 (20 watt output) with 18 ah Battery + 45 w Solar:
(52.6 pounds)

Transmit Time	Current while Transmitting	Current while Receiving	Receive Time
2 hours (120 min)	8.02 amps	3.71 amps	13.74 hours
1 hour (60 min)	4.01 amps	7.72 amps	28.59 hours
0.5 hours (30 min)	2.00 amps	9.73 amps	36.04 hours
0.25 hours (15 min)	1.00 amps	10.73 amps	39.74 hours
0.125 hours (7.5 min)	0.50 amps	11.23 amps	41.59 hours

The tables above reflect the capacity of the various solar panel systems. The 13 watt solar panel system is lightweight and installed quickly. But, it produces a low current output. The 45 watt solar panel system produces a higher current output. But, it is heavy and requires assembly.

For 24 hour coverage, two solar panel systems will be required. One system can be charging a battery while it is connected to a transceiver during daylight hours. The second solar panel system will be charging a battery for use at nighttime.

The transceiver power output required, the portability of the system required, and the time of operation for a particular event will determine which system should be chosen.