BUILD A PORTABLE SOLAR SYSTEM

Mike Renner
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NTREG is a sub-chapter of the Texas Solar Energy Society…
which is a sub-chapter of the American Solar Energy Society.

www.ntreg.org
www.txses.org
www.ases.org
Choose the System Size

What device(s) do you want to power?

When do you want the power the device(s)?

How long do you want to power the device(s)?
COMPONENTS

INVERTER
CHARGE CONTROLLER
FUSE / CIRCUIT BREAKER
WIRE
TERMINAL BLOCK
CONNECTORS
BATTERY CHARGER
BATTERY
BOX

READ ALL COMPONENT MANUALS!
Short Course in Electronics
Series / Parallel
Terminology

E  Voltage
I  Amps (Current)
R  Resistance
W  Watts (Power)
KW  Kilowatt (1,000 Watts)
KWH  Kilowatt Hour
OHM'S LAW

\[ V = IR \]

\[ I = \frac{V}{R} \]

\[ R = \frac{V}{I} \]
OHM'S LAW WITH POWER
OHM'S LAW

\[ I = \frac{E}{R} \quad P = E \times I \]

\[
\begin{align*}
I &= \frac{P}{V} & 60 \ W / 120 \ V &= 0.5 \text{ amps} & 60 \ W / 12 \ V &= 5 \text{ amps} \\
R &= \frac{E}{I} & 120 \ V / 0.5 \text{ amps} &= 240 \text{ ohms} & 12 \ V / 5 \text{ amps} &= 2.5 \text{ ohms} \\
P &= E \times I & 120 \ V \times 0.5 \text{ amps} &= 60 \ W & 12 \ V \times 5 \text{ amps} &= 60 \ W \\
I &= \frac{E}{R} & 120 \ V / 240 \text{ ohms} &= 0.5 \text{ amps} & 12 \ V / 2.5 \text{ ohms} &= 5 \text{ amps}
\end{align*}
\]
Terminology

What's the difference between Power and Energy?
Answer:

**POWER** = Volts x Amps

120V x 10 A = 1,200 Watts or 1.2 kilowatts (KW)

**ENERGY** = Power x Time

1.2 KW x 5 Hours = 6 kiloWatt-hours (kW-h)
WIRE GAUGE

Cross sections of Copper Conductors

18: low voltage for doorbells, thermostats, small appliances wiring & cords
16, 14, 12, 10: 120/240V for lighting and wall outlet circuits
8, 6, 4, 2: 240V for appliance circuits, service entrance conductors and subfeeders
1/0, 2/0:
WIRE CHART

COPPER WIRE RESISTANCE

<table>
<thead>
<tr>
<th>Gauge</th>
<th>10' Feet/Ohm</th>
<th>1000' Feet/Ohm</th>
<th>1/0' Feet/Ohm</th>
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WIRE SIZE vs VOLTAGE DROP

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Max. Wire Feet @ 240 Volts, 1 Phase, 2% Max Voltage Drop

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<th>Vol-Amgs</th>
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LET'S DO SOME MATH FOR WIRE RESISTANCE

12 GAUGE WIRE = 1.619 OHMS PER 1,000 FEET
1 FOOT = 0.001619 OHMS
20 FEET = 0.03238 OHMS
40 FEET = 0.06476 OHMS
100 WATT SOLAR = 18 V @ 5.5 A
200 WATT IN PARALLEL 18V @ 11 A
Voltage Drop = 0.06476 X 11 A = 0.71V / 18V = .039 = 3.9%
(LOSS IS 7.8W)
0.01619 + 0.36476 = 0.04857 OHMS x 11 A = .534V / 18V
= .029 = 2.9%
200 WATT SOLAR PANELS IN SERIES

200 WATTS AT 18 V x 2 = 36 V @ 5.5A
WIRE RESISTANCE: 0.04857 OHMS x 5.5 A = 0.267 V
0.267 V / 36 V = 0.0074 OR .74%
POWER LOSS: 5.5 A x 0.267V = 1.4 WATTS

FUTURE EXPANSION: 400 WATTS SOLAR
36 V @ 11 A
0.04857 OHMS x 11 A = 0.53 V / 36 V = 0.0148 OR 1.4%
POWER LOSS: 11 A x 0.53 V = 5.8 WATTS
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<th>#8</th>
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System Size and Type

- Fan
- Lights
- Cell phone
- Lab Top
- computer
- TV, Radio
- Coffee pot
- Hot plate
- Water pump
- Air conditioner
- Small cabin

What will the system power?
When is the power required?
How long is the power required?
Types of Portable Solar

Direct solar
Solar with battery storage
Solar with battery storage and voltage converting
Direct Solar

- Lowest number of components
- Lowest cost
- Easy to assemble
- Less to go wrong
- Requires light to operate
Direct Solar Components

- Solar panel
- Safety device
- Wire
- Load
<table>
<thead>
<tr>
<th>Solar Panels</th>
<th>Amorphous</th>
<th>Multi-crystalline</th>
<th>Mono-crystalline</th>
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<tr>
<td></td>
<td>7-13%</td>
<td>13-16%</td>
<td>15-20%</td>
</tr>
</tbody>
</table>
Solar Thin Film or Amorphous
7-13%
Solar Panel Data Plate
Safety Device

Do Not Use AC Breakers in a DC Circuit
Safety Devices
12-24 VOLT DC             150 VOLT DC
Direct Solar

DC LOAD MATCHES PV VOLTAGE AND WATTAGE (FAN, PUMP, ECT.)
Direct Solar

Water pump

13.6 V
4.0 A
54.4 W
### Solar Panel Data Plate

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<tr>
<th>Specification</th>
<th>Value</th>
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<tr>
<td>Current at Pmax (Imp)</td>
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<td>Maximum Series Fuse Rating</td>
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All technical data at standard test condition

AM1.5  E=1000W/m²  T=25°C
Direct Solar
Direct Solar
Is it possible to draw 200 watts from a 100 watt solar system?
YES!

IF the solar system contains a battery.
Portable Solar with Battery Backup

Solar panel
Safety device
Wire
Battery
Monitoring
Charge Controller
Load
BATTERIES

12 V, 7 A-H
0.119 kW-h

12 V, 35 A-H
0.42 kW-h

12 V, 125 A-H
1.5 kW-h
Sealed Lead-Acid AGM Battery
12 volt @ 100 AH = 1.2 kW-h
6 Volt Battery

Golf Cart Battery
220 A-H  10.5 kW-h

Industrial Battery
464 A-H  22.2 kW-h
Lead Acid Battery Capacity

Trojan IND9 6V 220 lbs each
6 Volt 464 A-H @ 20HR rate = 3.87 kW-h
100 HR = 601 A-H @ 6 A of discharge
72 HR = 580 A-H @ 8 A of discharge
48 HR = 545 A-H @ 11 A of discharge
20 HR = 464 A-H @ 23 A of discharge
12V = 276W  24V = 552W  48V = 1,104W
10HR = 414AH @ 41A of discharge
12V = 492W  24V=984W  48V = 1,968W
5HR = 364AH @ 73A of discharge
Battery Life Cycle

The life of a battery is determined by proper maintenance and the Depth-of-Discharge or the amount of energy removed before the battery is fully recharged. One cycle is one discharge and recharge.

IND9-6V

- DOD  20%  30%  40%  50%  60%  70%  80%
- Cycles  5000  4000  3,400  2,800  2,100  1,800  1,500
Battery Monitoring
Battery Monitoring
Charge Controller

A charge controller is a device that prevents the battery from being overcharged. It's installed between the solar panel and the battery.

Types:
- Switch Mode
- MPPT
Charge Controller Switch Mode
Pulse Width Modulation (PWM)

120W PV 18V @ 6.66 A
Battery 11V @ 6.66A = 73.3W
Charge Controller Switch mode

12 volt 3.5 amp
50 watts

12/24/48 volt 40 amp
560/1120/2240 watts
Charge Controller
Maximum Power Point Tracker ("MPPT")

- Higher output per panel
- Allows a wider range of panels in a system
- Panel voltage can be much higher than battery voltage
- Less line loss and greater distance from panel to battery
  - Most have built in meters
  - Higher cost
MPPT Charge Controller with Meters

12/24/48V 30 AMP
420/840/1680 watts

12/24/48/60V 60 AMP
840/1680/3360/4200 watts
MPPT output of 1,020W
Switch Mode: 51.8V x 37.3A = 1,932W
With MPPT: 3,350W (a 1,418W improvement !)
Solar with Battery Backup
Solar with Battery Backup
Solar System with 120Vac Output

- Solar Panels
- Charge Controller
- Safety Devices
- Inverter
Inverter

An inverter is an electronic device that converts Direct Current to Alternating Current.

Types:
- Modified Sine Wave
- Sine Wave
- Sine Wave Inverter Charger / Hybrid
Modified Sine Wave
Modified Sine Wave Inverter
Low cost.
May harm electronic devices.
Sine Wave Inverter

300 Watt Pure Sine Wave Inverter

GREAT FOR:
- Laptops
- TVs
- Satellite
- Printers
- Computers
- Radios
- WiFi
- Chargers
Sine Wave Inverter
Sine Wave Inverter / Charger
Sine Wave Inverter Charger / Hybrid
4,000 Watt 120VAC        6,000 Watt 120/240 AC
Sine Wave Inverter / Charger for a Hybrid System
Put It All Together

What is the system going to be used for?

Purpose is to supply portable backup power for lights, communication, refrigeration, and to power a $\frac{1}{2}$ ton window air conditioner. It can also be used for power tools at construction sites, powering a sound stage and pumping water. It's also great for camping and hunting.
Power Required

Power: 1,000 Watts System @ 120VAC
Duration: Intermittent or 24 / 7

Components

PV, 4 each 250 watt panels total 1,000W
Battery 24 volt system, 4 each 12 volt @ 125AH/6KWH
Charge Controller Midnight Solar 30 amp MPPT
Inverter Exeltech XP1100
Solar Panel Data

- 4 panels wired in series/parallel
- 61.4 volts @ 16.3 amps
- Wire chart: 20A of #8 is good for 90 feet at 120V/2 = 45 feet.
- Two 15 amp breakers will be used, one for each series string.
Charge Controller

- Max input voltage 150 VDC
- Max output 30 amps
- Built in battery meter
- Built in 30 amp fuse
- 14.5V x 30A = 435W
- 29.0V x 30A = 870W
- 58.0V x 30A = 1,740W
Inverter

- Exeltech XP1100
- 1,100 WATTS 2,200W surge
- Input 24 VDC @ 45.8 amps
- Output 120VAC @ 11 amps
- Manual states to use 6 gauge wire for length under 5 feet.
- Protected by 50 amp breaker.
What type of system do you want?
COST

- 2 EACH 100 WATT SOLAR PANEL $264.00
- AGM 50AH BATTERY $196.00
- BATTERY MAINTAINER $82.00
- XANTREX 1,000 SW INVERTER $294.00
- MIDNITE "KID" CHARGE CONTROLLER $315.00
- MIDNITE "WHIZBANG" $43.28
- 500 A CURRENT SHUNT $24.34
- 2 EACH CIRCUIT BREAKERS $40.00
- HUSKY JOB BOX $54.00
- MISC HARDWARE / WIRE $100.00
- TOTAL $1412.62
PARTS SOURCES

• HOME DEPOT
• LOWES
• ACE HARDWARE
• PEP BOYS
• OREILLY AUTO
• NORTHERN TOOLS
• ECO-WORTHY.COM
• ACADEMY SPORTING GOODS
• CONTINENTAL BATTERIES
• MOUSER ELECTRONICS
• INFINIGI.COM
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