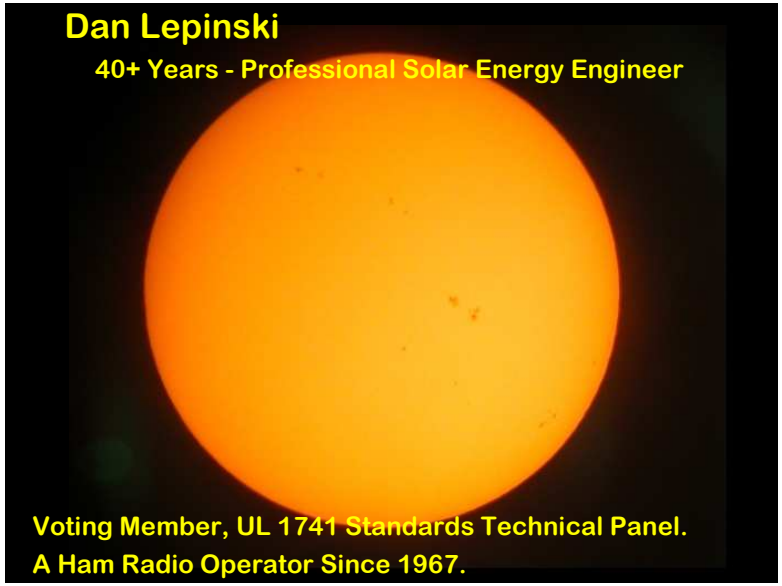


"Solar Power for Amateur Radio Operators"

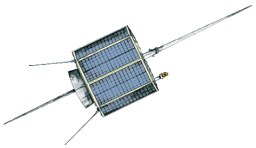
Tonight, we're going to discuss:

1) Solar Electricity – What It Is .. and How It Works.

2) Charge Regulators – Proper Care and Feeding of Batteries ...

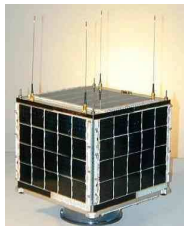
3) Batteries – How to Use (and Abuse) Them.

4) Inverters – Change Battery Direct Current into Alternating Current.



Amsat-Oscar 7, Nov 15 1974.

Amsat-Oscar 51, June 28, 2004.



"Solar Power for Amateur Radio Operators"

First .. Lets' review some basic terminology...

Photovoltaic ("PV"): **Electricity from light.**

Charge Controller: **Device to prevent overcharging a battery.**

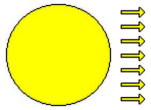
Maximum Power Point Tracker:
Optimizes energy transfer from PV.

Volts, Amps, Watts: **Electrical pressure, quantity, and energy.**

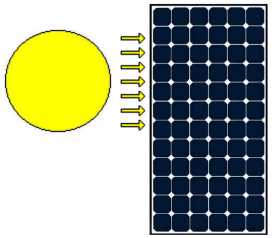
Watt-hours: **Quantity of electrical energy consumed over time.**

That said .. let's get started with Part 1 ...
"PV" .. and how it's designed into a solar electric system.

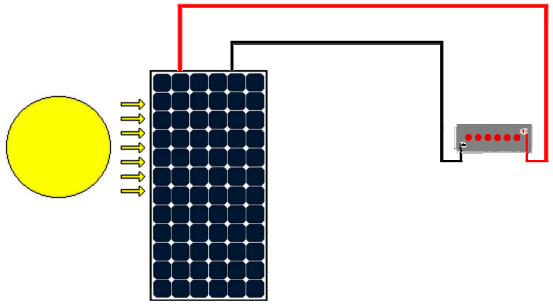
Everything starts with the sun ... and sunlight energy.



Add a photovoltaic module...

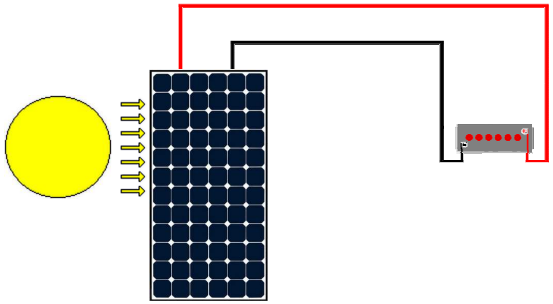


Add a photovoltaic module .. and a battery – we now have the most basic solar electric power system.



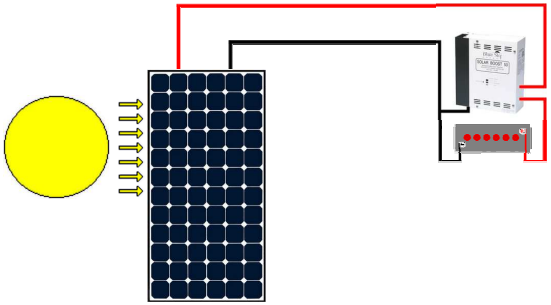
This system would work as configured .. but not reliably.

Why??



"PV" of any size cannot usually be directly connected to a battery without risking damage to the battery due to over-charging the battery.

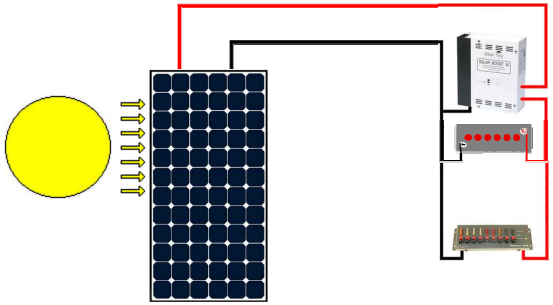
A charge controller is needed to prevent overcharging.



A good quality charge controller:

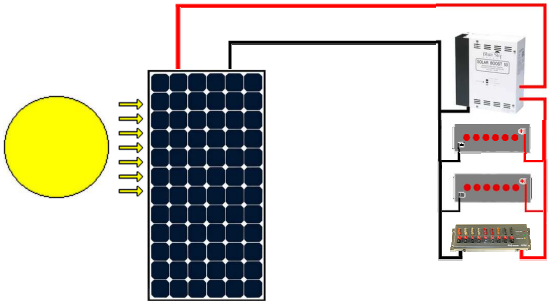
1) Prevents the battery from getting overcharged.
2) Adjusts the charge voltage based on battery temperature.

Next, we need a means of connecting the DC to our equipment...



Fused DC power distribution panels are available from several manufacturers that provide a convenient method to connect DC power to a variety of loads.

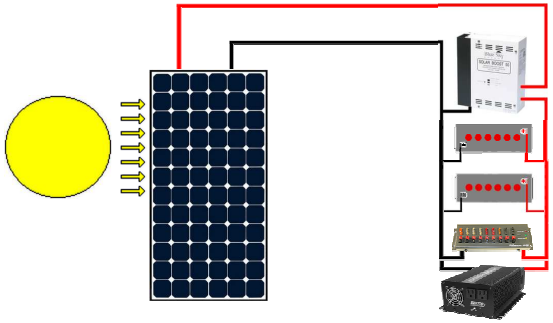
A second battery will increase energy reserves for overnight use, and/or cloudy periods.



"Best practice" recommends a maximum of two batteries in parallel. More than two in parallel tends to shorten battery life due to "circulating current".

If you need additional energy storage, use larger (higher capacity) batteries, not more batteries.

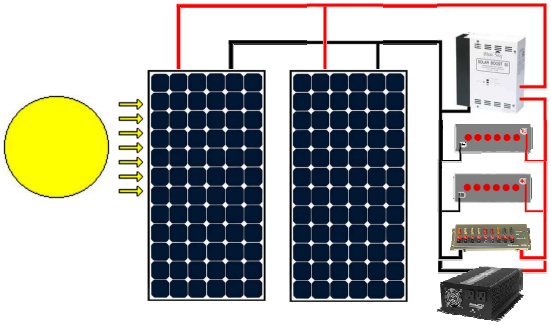
For AC loads, a "true sine-wave" inverter costs more, but is best for your equipment – and YOU!



Quality sine wave inverters change direct current into alternating current exactly like what we get from the power company.

True sine-wave ac allows sensitive electronics to work better, motors run faster and cooler, and most importantly .. create less radio interference!

More PV can be added for increased charging capability.



PV may be connected in series to obtain higher voltage, in parallel for more current, or both.

Voltage and amperage ratings for each PV must be taken into account to successfully connect PV together.

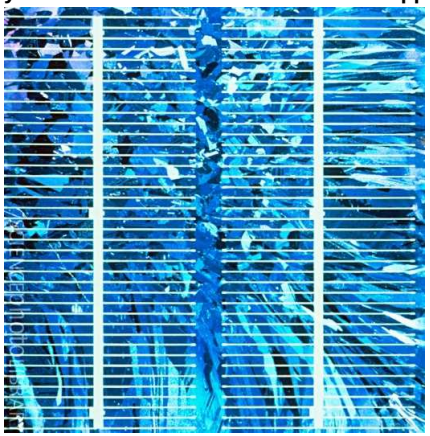
There are three common types of photovoltaics today.

This is a “single-crystal” (mono-crystalline) silicon cell.

Highest efficiency, but also the most expensive of the solar technologies.

Multi-crystalline cells. Also called “poly-crystalline” cells.

They vary from dark to brilliant-blue mosaic in appearance.



Slightly less efficient than mono-crystalline cells, but lower in cost (dollars per watt).

The newest PV technologies are “thin film”: amorphous silicon, cadmium-telluride (“CdTe”), and copper-indium-gallium selenide (“CIGS”).

Amorphous Silicon

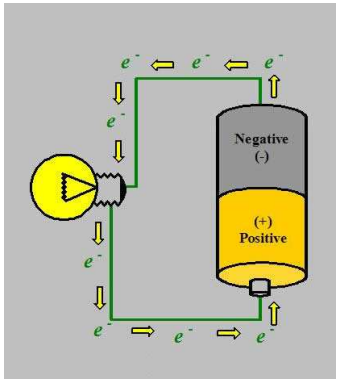
Cd-Te

“CIGS”

Medium efficiency. Lowest potential cost in dollars-per-watt.

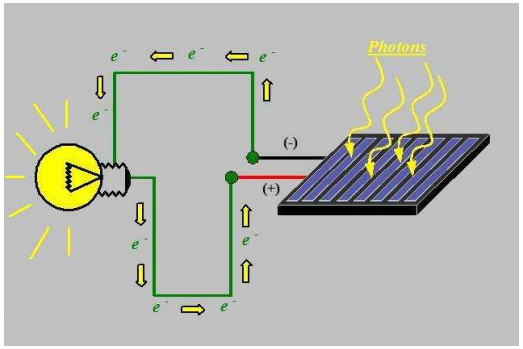
Thin film PV maintain higher percentage of their output wattage in hot environmental conditions compared to crystalline technologies, and may even outperform crystalline PV in hot environments.

So .. How does "PV" generate electricity from sunlight?



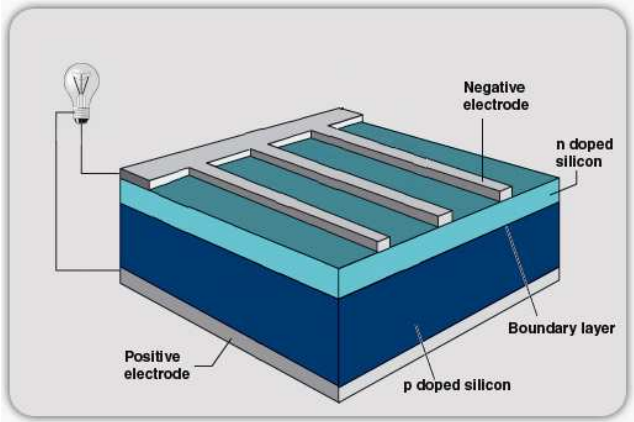
PV, like the cell above, has its "negative" side "up" .. facing toward the sun.

So .. How does "PV" generate electricity from sunlight?



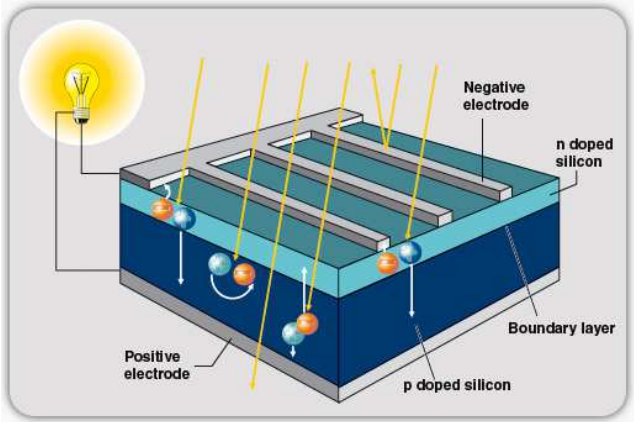
Sunlight is composed of "photons" – bundles of energy that strike atoms in the PV, freeing electrons .. similar in manner to how a bowling ball strikes the pins (if your aim is good!).

How does "PV" generate electricity from sunlight?
Let's look at the construction of a PV cell...



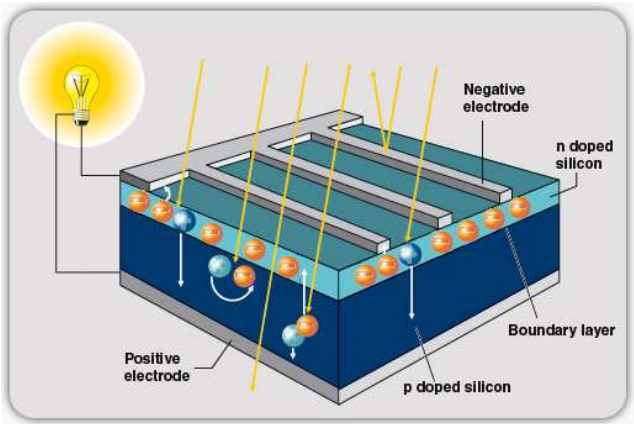
There are two layers: an 'N' layer, and a 'P' layer. Sound familiar?
A PV cell is a big light-sensitive diode!

How does "PV" generate electricity from sunlight?



Photons are shown striking atoms in the PV cell.
This knocks electrons loose from the protons, freeing them.

How does "PV" generate electricity from sunlight?



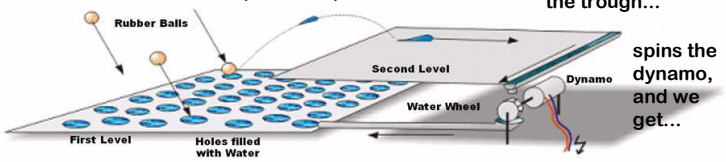
Freed electrons migrate to the cell surface, and are replaced by electrons from lower layers. We have current flow!

How does "PV" generate electricity from sunlight?

The sun is a perpetual source of energy. In this example, let's think of the sun's energy as rubber balls that are launched at a tray with water in a group of holes (think "cupcake" tray) ...

Water splashes up to "level 2"...

where it runs into the trough...



spins the dynamo, and we get...

electricity!

Water then runs back to the tray, and the process repeats.

Unlike water that evaporates, the technical aspects of photovoltaics that allow for power generation don't "go away".

PV "Top 10" Questions:

1) Is PV "efficiency" important?
2) Should I build my own PV to save money?
3) Do PV make electricity in cloudy weather?
4) What are PV made of?
5) Do PV work better in hot weather?
6) Can PV make electricity and hot water at the same time?
7) How long do PV last?
8) What about hail?
9) Why is PV so expensive?

.. And finally...

10) How much PV will I need to put on my house to:
    a) run my air conditioner .. or ...
    b) have a zero electric bill?

Comments or Questions?

Part 2: Charge Controllers

Charge Controllers:

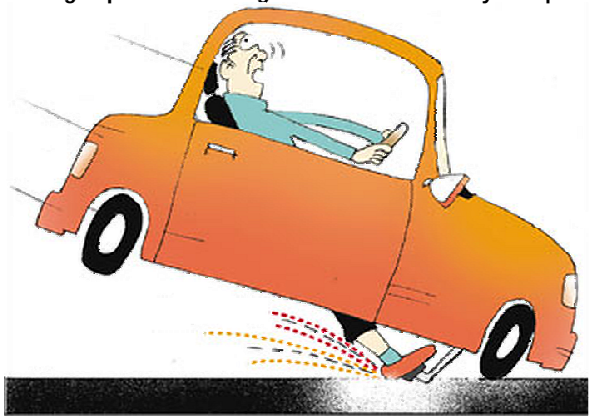
1) What is a "charge controller"?
2) Why should I use one?
3) Linear vs. Pulse on/off vs. "MPPT" ("MPPT"??).
4) Why is temperature-compensated battery charging important?

Maximum Power Point Trackers:

1) What is a "Maximum Power Point Tracker" ("MPPT")?
2) Why are they helpful?
3) At What Cost?

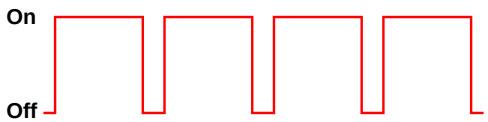
Ah Ha!

A "linear" charge controller is like having one foot pushing on the gas pedal and using the brake to control your speed.

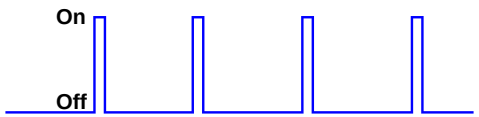


They work .. but waste a LOT of energy and usually run hot. Few linear charge controllers are used today.

A "pulse" charge controller turns on and off, like this...



An "on" condition most of the time indicates the battery is receiving a strong charge...



When a battery is nearly fully charged, the current pulses are reduced to little "blips", reducing energy flow and preventing over-charge.

While more efficient than "linear" controllers, "pulse" charge controllers still have drawbacks. Anyone know what??

Examples of "pulse" Charge Controllers...

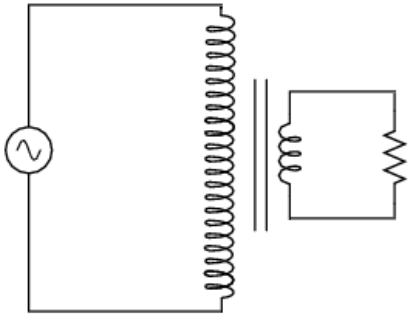
ProStar by Morningstar...

C40 by Xantrex...

Harbor Freight "Special"

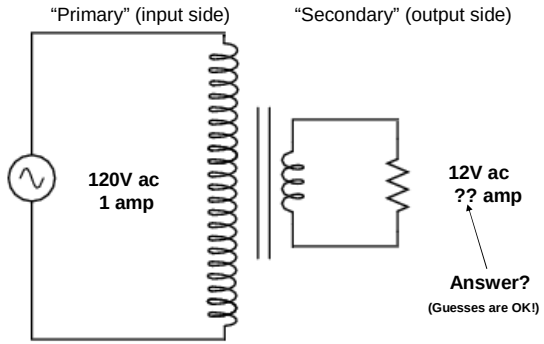
Note! (It's rated for 30 amps, but look at the small wire!)

So .. How does a "Maximum Power Point Tracking" Charge Controller Work?



A "MPPT" is a direct current ("DC") device .. but let's start by considering the transformer-based "AC" circuit above.

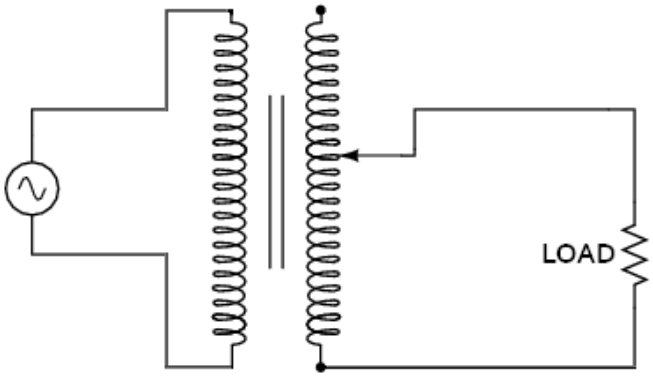
What if the transformer stepped down from 120 volts ac to 12 volts ac using the values below?



On the "secondary" (output) side of the transformer, we have 1/10 the voltage of the primary, but at 10 times the current of the primary. 120 volts x 1 amp = 12 volts x 10 amps = 120 watts.

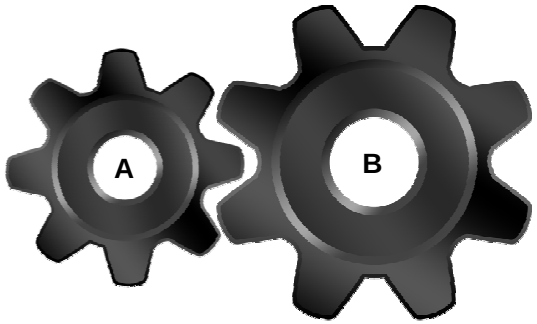
Remember: Current charges batteries. The greater the current, the higher the rate of charge.

Next, consider a continuously variable transformer. It can be adjusted to vary the output voltage from zero up to the input voltage – just like a volume control.



A maximum power point tracker does this task electronically and automatically – but for DC instead of AC.

A MPPT unit is like gears. Driven gear 'A' may be spinning more rapidly than we can use. By coupling it to gear 'B', gear 'B' turns slower, but offers more "torque" ("twist") than gear 'A'. In this case, we would take our output from gear 'B'.



Too much speed is like having too high a voltage for our load. By electronically decreasing the voltage, a MPPT can increase the available current by the same percentage the voltage decreases. Half the voltage = double the current.

Examples of "Maximum-Power-Point-Tracking" Charge Controllers...

Blue Sky Energy "Solar Boost"

MidNite Solar "Classic"

Morningstar "SunSaver MPPT"

Outback Power

BZ Products MPPT 500

Comments or Questions?

Part 3: Energy Storage ("Batteries")

Batteries are available in several different types. Each has its own advantages and drawbacks...

1) "Flooded" or "Wet-Cell" Lead-Acid. Always open (to add distilled water).
2) Marine or "Trolling-Motor" Batteries. May be sealed or open.
3) Valve-Regulated Lead-Acid ("VRLA"). Always sealed.
4) Absorbed-Glass Mat ("AGM"). Always sealed.
5) Gel-cell batteries. Always sealed.

More About Batteries:

True deep-cycle batteries are rated amp-hours or watt-hours for 8 or 20 hours, never "cold cranking amps", "cranking amps, or "reserve amps".

#1 Lead-acid battery killer: **Exceedingly deep discharges.**
#2 Lead-acid battery killer: **Heat.**
#3 Lead-acid battery killer: **Sulfation caused by not fully recharging a battery immediately after use.**

Examples of Various Battery Types...

AGM VRLA

Gel Cell

Flooded Lead-Acid

Sealed Lead-Acid

"Marine"

AGM

Comments or Questions?

Part 4: Inverters – Converting DC to AC

Inverters come in three types:

1) Square wave output.

2) Modified square wave output. (Marketing/sales people call this "modified sine" wave to make it sound better to consumers.)

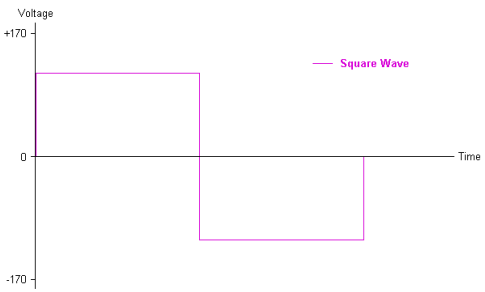
3) True sine wave output.

Square wave.

Modified square wave.

True sine-wave output.

Square Wave Inverters...

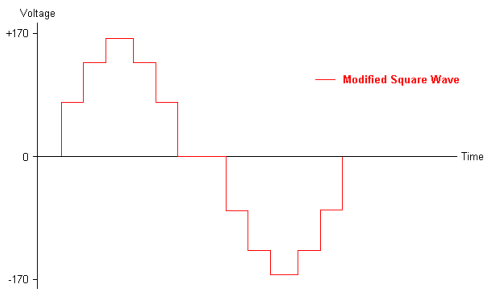


Cheapest type of inverter to manufacture and sell.

Very stressful and often damaging to electronics and electric motors.

Not recommended for situations requiring a reliable AC power source.

Modified Square Wave Inverters...

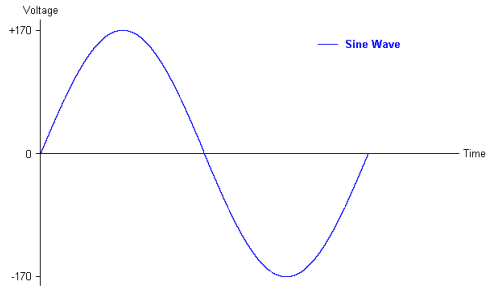


A compromise between square wave and sine wave.

Significant distortion appears in electronics as hum or noise.

Electric motors operate up to 10% slower and much hotter than with sine wave power.

<u>True</u> Sine Wave Inverters...

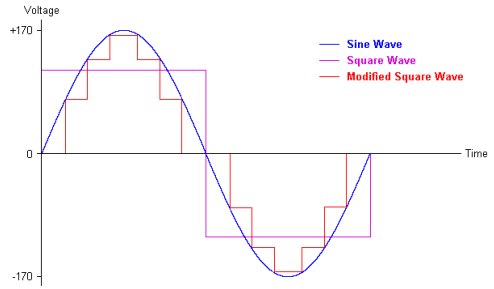


Exactly the same as electricity from the utility company.

Sine-wave AC is "friendly" to sensitive electronics, motors, and other loads.

More expensive, but also generally more reliable than the other types.

All Three Waveforms Together for Comparison...



Some Inverter Technical Tips to Keep in Mind...

What ...	Why it's important...
* Rated duty cycle	Cheap inverters overheat easily, leading to failure.
* Surge capability	How much overload, and for how long? Think "motors, compressors, etc.".
* Voltage and frequency stability	Stable power is important for rapidly varying loads such as SSB transmitters.
* EMI/RFI Issues	Interference can render a receiver unusable.
* Quality & Reliability vs. Cost	Power sources should be as reliable as possible, especially for times of emergency. Cheap=undependable.

Comparison of DC vs. AC as a Power Source...

DC Power:

Some loads can be powered directly from the battery.

No power loss in an inverter. (Good inverters are typically 90% efficient.)

Be mindful of cable size vs. distance vs. current.

Use connectors with proper amperage ratings.

Fuses and circuit breakers are important.

AC Power:

Virtually universal source for power supplies and other loads.

Loads can be remote from the inverter by use of extension cords.

Useful for tools and some types of lighting.

Square-wave and modified square-wave output may overheat some power supplies, motors, and other loads.

Low-cost inverters are virtually never rated for continuous use at full power.

Wiring – It's Important to Do It Correctly!

Use proper conductors, connectors and hardware rated for the current.

Ensure all connections are tight.

Protect your equipment. Use fuses and/or circuit breakers.

Don't skimp on wire size. PV systems can have a LOT of current flowing. Under-sized wire causes excessive loss, which in some situations can lead to overheated conductors and possibly fire.

So .. What Do I need to Power My 12V Ham Station?

1) PV. Size determined by your equipment power needs and your operating time.

2) Charge regulator. "Maximum Power Point Tracking" model strongly recommended. PV ratings determine the regulator's specifications (and v/v).

3) 12V battery – capacity determined by your loads and operating conditions. If located indoors, use SEALED batteries. Always put batteries in a vented safety enclosure, and vent the enclosure to the OUTSIDE.

4) **Fused power distribution** in all circuits.

How Much Power Will This Provide?

1) One 200-watt PV module will generate approximately 1 kW-h per day in bright sunlight. (Based on 5 average "sun-hours" per day.)

2) System efficiency losses reduce this figure by 15-25%, and even more if the batteries are old or in poor condition.

3) A modern 200-watt single-sideband station operated 75% of the time in receive mode, 25% in transmit mode, with 1A current draw in receive will consume approximately 82 watt-hours per hour of operation.

4) A 35 watt FM station power consumption on a 75% / 25% basis would be approximately 25 watt-hours for 50% efficient transmit, 12W receive.

5) Used 24 hrs, a SSB station will consume 82 Watts * 24 hrs = 1,968 W-h. This is exclusive of lights, computer, and other accessories.

6) Design your solar backup system accordingly. Deep-cycle batteries yield the best "dollars per watt" (and life) if discharged 50% or less.

Ohhh my aching head!

Some Final Words About Solar Power:

Emergency Systems.

Hurricane Andrew – August, 1992...

Hurricane Katrina – August, 2005...

Hurricane Ike – September, 2008...

Moore, Oklahoma – May 20, 2013...

My Emergency Solar Power Systems – March, 2002...

This is how my systems were configured in 2002.
All four were used by first responders after Hurricane Katrina in 2005.
They were retired in 2009. I donated the PV to Habitat for Humanity.

Generation 2 – March, 2010 ... The "Solar Shuttle"

The "Solar Shuttle" has provided power for numerous emergency services, environmental and other events, and public service including Field Day.
It can handle 15+ stations silently, reliably, and fuel-free ... all weekend!

The Solar Shuttle Powered Field Day for...

Dallas, Texas Amateur Radio Club Field Day, 2010.

North Richland Hills, Texas ARC Field Day 2011, 2012 & 2013.

... and is already reserved by ham clubs for Field Day 2014 & 2015.

Your solar power system need not be this elaborate to be effective!

Solar Power Can Be as Simple as This System:

.. with a maximum-power-point-tracking charge controller and 250 watt sine wave inverter on the back.

Here, a hand cart provides the framework for a complete portable system. "Thin-film" PV, on the front, a 12V deep-cycle battery on the pedestal ...

Small enough to easily transport on a moment's notice. Capable of providing 12Vdc and 120V ac emergency power for a variety of needs.

No matter what the future will be, one thing is certain: Some type of energy will be needed to help power it... and to that, the solution comes up every morning.

Comments or Questions?

Dan Lepinski
Dan@ntree.org