The Extremely Serious

DIY Solar Electric Power Starter Course

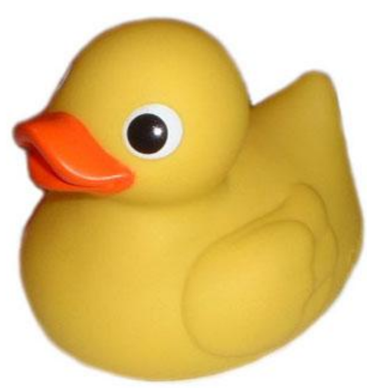
Lesson # 7

Inverters: It's (Mostly) About Making Waves

By

the Trolls and Droids
at solarDIYpanel.com

http://solarDIYpanel.com



Lesson # 7

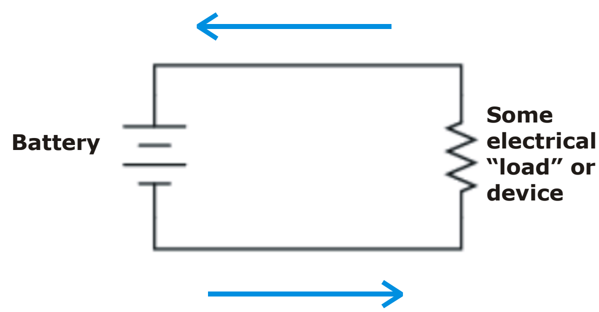
Inverters:
It’s (Mostly) About Making Waves

The Inverter is what changes the direct current (DC) from your battery to alternating current (AC) needed by many electrical devices. If you are going to run just simple 12 volt DC (direct current) devices off your batteries, then you won’t need it. However, most of us will need to run AC equipment.

How AC is different from DC

Direct current flows only in one direction.

Period. End of story.

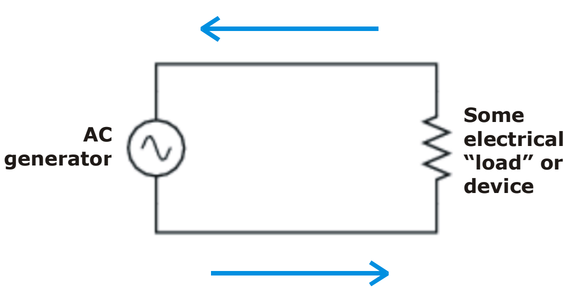


With alternating current, however, there is a bit more to tell.

The stuff that the power companies send us doesn’t flow just one way; it reverses its direction 60 times every second. (That’s why they call it 60 cycles per second.)

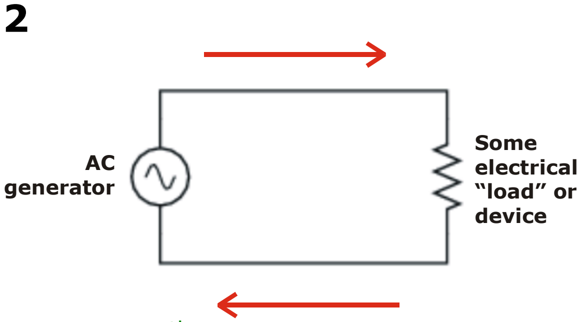
There are some very good reasons for having it do this but that discussion is for another time.

1



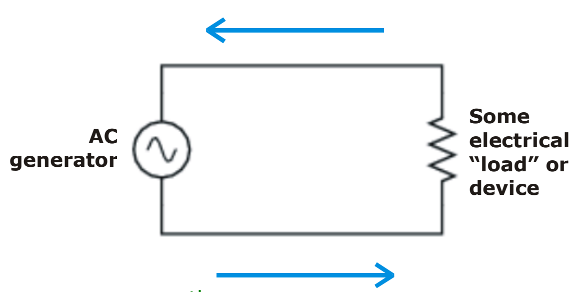
In the first moment, it is going one way.

2



Then 1/60th of a second later, it is reversed and going back the other way.

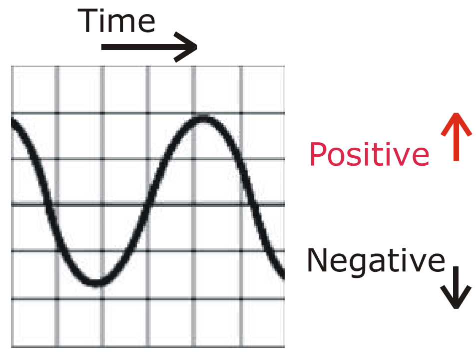
3



Another 1/60th of a second goes by and it has reversed yet again, and so on…

In a wire with alternating current, the electricity is running in one direction and then the other thus "alternating" its direction.

The smoothness with which this current flows is described by a "sine wave" where, if you were watching electrons flow from one point in the wire, they might appear to go first one way and then the other.

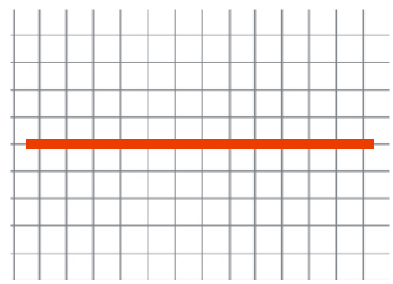


This back and forth business happens because an AC generator is really a coil of wire spinning inside of a magnet. As the negatively charged electrons in the copper wire are tugged on by the magnet first in one direction and the other, a quickly reversing flow is started in the coil.

AC generator

DC electricity, on the other hand, looks like this:

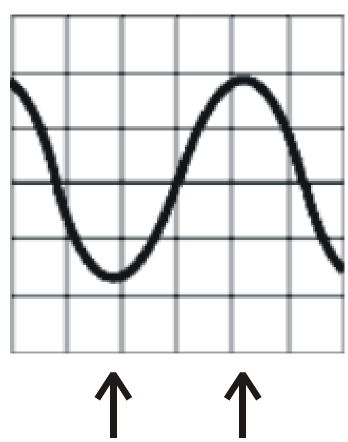
It's flat because there is no wave, no alternation between positive and negative.



Looking a bit closer at the AC wave, what that shape is really telling us is that between the two arrows in the figure to the right, the current is starting out flowing in one direction and within the span of 1/60th of a second, smoothly reversing to the other direction.

You'll notice that it is very even with no sudden jerks or changes. It all happens in 1/60th of a second, but as you can see, it is completely smooth transition.

And it is this smooth precisely because of how it was made in the first place: A coil of wire spinning smoothly between the two poles of a magnet.



1/60th of a second

The problem the inverter has to solve is how to make nice, curvy alternating electricity out of flat DC. So how is that supposed to happen?

Square Wave Inverters

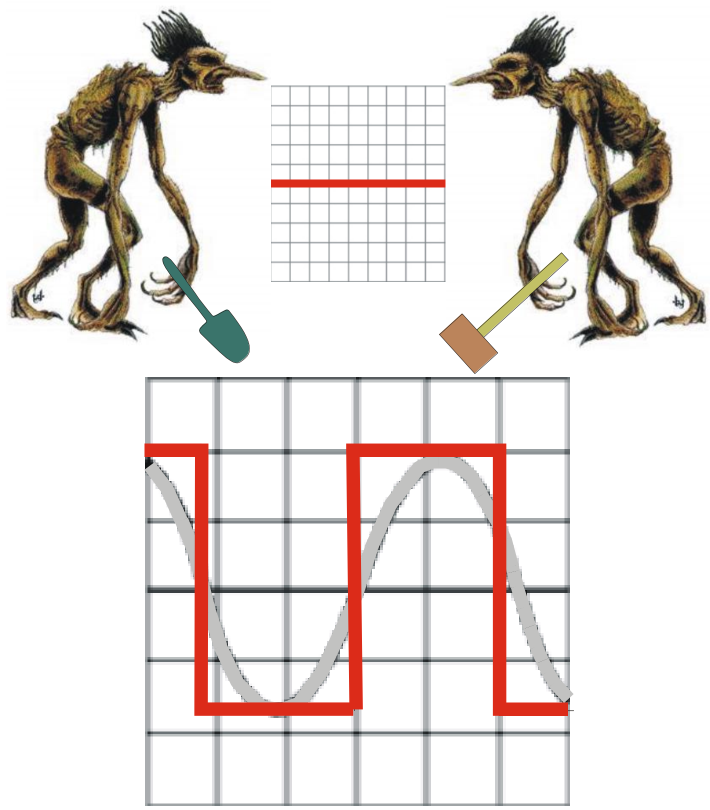
One way to do this is to hire a couple of cheap trolls.

Generally speaking, this isn't too good an idea because their methods are frankly quite crude. They aren't terribly imaginative and even their best efforts leave something to be desired.

After hours of careful consideration and a lot of pounding, they came up with something they call the "square wave" (duh).

The trouble with this kind of electricity is that it isn't smooth. The transitions are too jerky and the corners are too sharp for the innards of most modern equipment.

You can use this stuff for some simple devices but generally it goes down like bad moonshine.



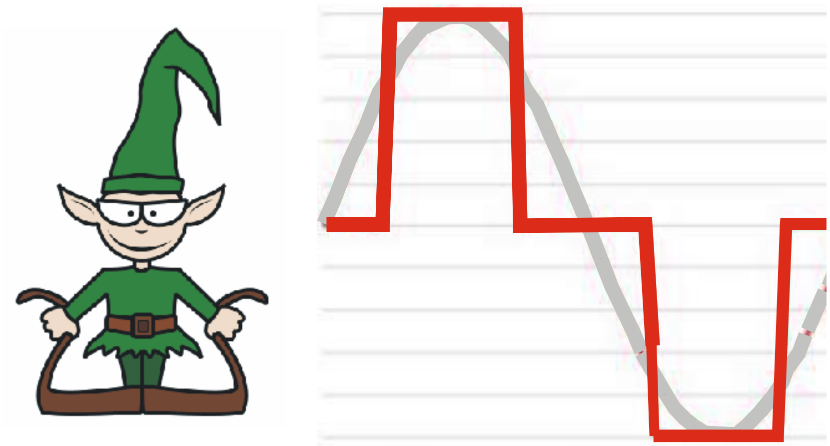
The Trollish notion of a sine curve

Mostly you won't find any inverters nowadays that produce AC like this.

Modified Sine Wave Inverters

The next option is the most common; the ***Modified Sine Wave inverter.***.

Being quite inventive, elves produce a much more useable result than trolls. Really it is just an improved version of the trolls square wave and is still a bit "noisy" (has corners and edges) but in fact works pretty well in most modern equipment.



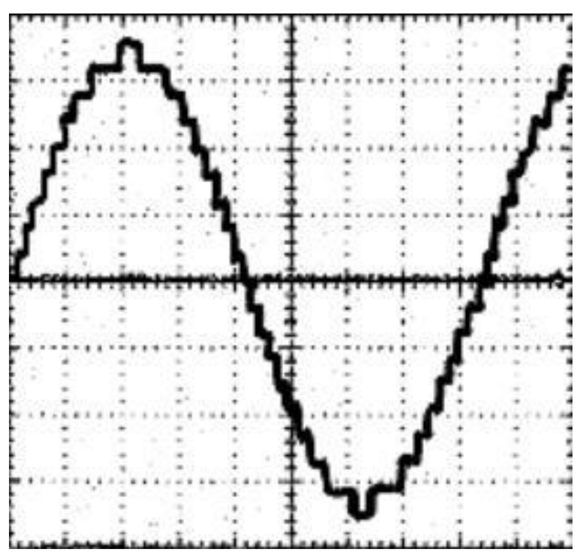
The Elvish "modified sine wave"

However, there are devices which find Elvish electricity indigestible. These include items such as laser printers, some TVs, ultra modern washing machines, electronic control systems, some medical equipment and rechargeable or variable speed tools may not function correctly with modified sine wave AC. Some motors will live shorter lives if fed a steady diet of only modified sine wave AC.

So, for those more finicky pieces of equipment, there are other options.

Stepped Sine Wave Inverter

This one starts with the same idea as the modified sine wave except that it adds many more "steps". It is a compromise between "good" (modified sine wave) and "best" (pure sine wave)

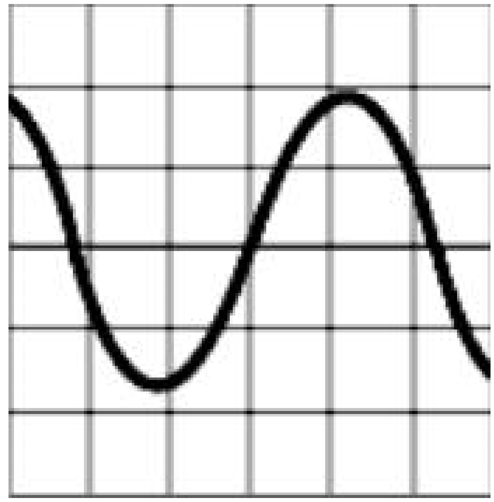


Their output AC power is considered "cleaner" (less jagged) and is often more acceptable to the sensitive devices.

Different stepped sine wave inverters may have more or few steps and are usually progressively more expensive as the number of steps increase.

Pure Sine Wave Inverter

This type of inverter is the top of the line.



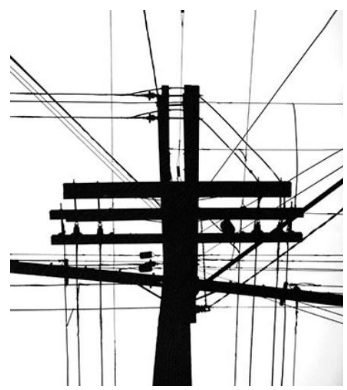
They deliver the "cleanest' power, same as the utility companies. In fact, pure sine wave inverters can provide even cleaner power since utilities have to deal a whole range of power noise and disruption problems – from the effects of lightning and sunspots to equipment failures of all types resulting in power surges or power reductions.

Pure sine wave inverters are usually as much as 75% more expensive than modified sine wave inverters.

Ways to Use Inverters

There are three general functions most people expect of inverters:

Tie into the electrical grid



Grid-tie inverters make AC electricity so you can sell it back to the electric company.

They must produce pure sine wave electricity for this purpose and are required to shut down in the event of a power loss (blackout) to prevent damage to power utilities and utility personnel who may be working on restoring power (called "anti-islanding protection"). For this reason, grid-tie inverters cannot provide you with backup power in the event of a power emergency.

In general, home-built solar power systems would not be designed to sell power back to the utilities and thus this type of inverter would not be necessary.

Stand alone

Stand-alone inverters are designed to run off-grid systems without interfacing with the external utility power distribution network. This is typically what an off-grid household would use.

Make an uninterruptible solar power supply

This is the **battery backup inverter** which can perform the functions of both of the above and often includes an internal charge controller permitting it to serve the charging requirements of the battery bank.

Thus it can shunt power back to the external utility grid when there is power in excess of what is required by the solar power system batteries. In the event of a utility power failure, battery backup inverters will automatically call up local battery power.

Sizing an inverter for your system

First some definitions:

Surge Loads (also known as Peak or Starting Loads) are the electrical demands equipment makes when starting up. For example, typically a motor requires 2 to 5 times more wattage to start up than after it has come to speed.

Thus your refrigerator (which stops and restarts many times a day), might normally need only 1,000 watts while running but to START UP might need 3,000 watts.

Continuous Loads are the electricity demands equipment makes during their normal operating phases.

Once your refrigerator has started, it needs less energy than when it was trying to get up to speed.

General Steps to Size an Inverter

There are three basic steps you have to take to figure out the wattage ratings for the inverter you will need:

1. **Calculate the Continuous Loads**: Add up all the normal operating wattages of the equipment you expect to be running simultaneously.
2. **Calculate the Surge Loads:** Add up all the surge or peak wattages of the equipment that ***might possible be starting at the same time.***

   Warning! When sizing an inverter for a system, the safest way to do it is to look up the surge loads for all the equipment you are likely to be running. Some devices such as pumps, refrigerators and air conditioners can have surge power demands 3 to 7 times their continuous power ratings. It is extremely important to know this because startup loads can be very high if they occur simultaneously and it can trip the circuit breaker in your inverter.
3. **Adjust for Inverter inefficiency:** As with a lot of electrical equipment, there is some loss of power.

   Pure Sine Wave Inverter loses about **10%.**

   Modified Sine Wave Inverter loses about **15%.**

   Sample Calculation:

Device	Continuous loads	Surge loads
Refrigerator	200 watts	400 watts
Power saw	1,500 watts	3,000 watts
Washing machine	1,250 watts	2,500 watts
Well pump	1,250 watts	2,500 watts
Lights	1,500 watts	none
Computer equipment	50 watts	none
Small misc equipment	30 watts	none
Total surge loads	**5,780 watts**	----
Total continuous loads	-----	**8,400 watts**

If you are going to use a modified sine wave inverter, now compensate for the inverter's inefficiency (power loss) rating:

	Raw totals	Add 15%
Continuous loads	5,780 watts	**6,647 watts**
Surge loads	8,400 watts	**9,660 watts**

Therefore assume you would need an inverter that provides 7,000 watts continuous and 10,000 watts surge, though typically surge (peak) wattage is provided at 2x the continuous load rating.

Thus your inverter would probably be rated at 7,000 watts continuous load and 14,000 watts peak load.

Links to Previous Lessons

Lesson 0 – Overview

Lesson 1 – What is a Solar Cell?

Lesson 2 – What is a Solar Panel? Part A

Lesson 3 – What is a Solar Panel? Part B

Lesson 4 – An Introduction to Charge Controllers

Lesson 5 – Storage Batteries

Lesson 6 – Charge Controllers Revisited

