DC vs. AC

Up to this point, we have been thinking exclusively about DC electricity — electric current that flows in one direction, from negative to positive.

I'm sure that you're already familiar with the terms "DC" and "AC" — AC referring to the "alternating current" provided by the power company. In the U.S. the standard is 120-volts, with a precisely controlled frequency of 60-Hz. The majority of other countries use 220-volt, 50Hz power systems.

Edison vs. Westinghouse

Ever wonder why we use AC power and not DC? Almost everyone does, but not many know why, or the story behind it.

Thomas Edison invented the first practical incandescent light bulb in 1879. It was a time when the Industrial Revolution was in full swing, and individual entrepreneurs were creating new industries and amassing great wealth. Edison was keen to get into the game; to make his own fortune — not only by selling the light bulbs, but also by licensing the patented DC electricity system needed to operate them.

Beginning in Detroit, there was a rush to build power plants all across the United States, guaranteeing him and his descendants a perpetual fortune in royalty payments.

But there was a hitch.

As you've already learned, there is no perfect conductor. Edison's 110-volt DC distribution systems were limited by the voltage drop of the wiring, to the extent that anyone further than a mile or so from a power generating station was not a prospective customer.

Hoping to get past that limitation, he hired a very bright Serbian engineer to work on the problem. That engineer, whose name was Nikola Tesla, came up with the idea of using alternating current, instead of Edison's pet direct current.

The problem, as he saw it, was this …

$$E_{TL} = I \times R_{TL}$$

… Ohm's Law, showing that the voltage lost along the transmission line was a function of the line's resistance and the load current. The longer the line, the higher its overall resistance. The more customers that got hooked up, the higher the load current.

The only solutions, in Tesla's mind, were

(a) to increase the size of the wiring in order to reduce its resistance, else (b) to reduce the current.

Increasing the wire size wasn't practical because of the huge wire size required and costs involved in that approach.

A better solution would be to reduce the current. This made sense because …

$$P = I \times E$$

As James Watt had shown about 100-years earlier, wattage was the product of current and voltage. To deliver the same amount of power, Tesla proposed that a sharp increase in voltage would result in a proportionate decrease in current, thereby resulting in the much-needed reduction in voltage drop across the transmission lines.

But in order to accomplish that, the system would need to be converted from direct current to alternating current, so that the high voltage could be stepped-down through a transformer at the point of use to 110-volts.

Edison, being more of an experimenter and self-promoter than an engineer, refused to hear of such a thing. Shortly thereafter, Tesla quit, claiming that Edison had wrongfully dismissed his work out of hand, and had also refused to pay him what was due.

Aiming to go into business for himself, Tesla contracted support in the form of George Westinghouse, and that's when the so-called *War of Currents* began.

Things got really down and dirty on Edison's part. He launched a smear campaign aimed at Tesla, Westinghouse and AC current, focused especially on his perception of the dangers of high voltage: *"Just as certain as death,"* Edison predicted, *"Westinghouse will kill a customer within 6 months after he puts in a system of any size."*

To support his assertions, Edison also became a participant in the invention of the electric chair! In replying to the inventor's invitation, he wrote that he did have some thoughts about the use of electric currents to dispose of, as he put it, *"criminals under sentence of death."* In another jab at Westinghouse, he went on to say, *"... the most effective of these are known as 'alternating machines,' manufactured* *principally in this country by Mr. Geo. Westinghouse, Pittsburgh.”*

Shortly thereafter, in 1888, he arranged a demonstration for the news media, featuring the electrocution of a small dog. About two years later, William Francis Kemmler of Buffalo, New York would go down in history as the first man in the world to be executed using the electric chair.

That first execution did not go well. In fact, it was horrifying to those who witnessed it — many being of the news media, who promptly sensationalized the grizzly details.

Edison called it being “Westinghoused”.

In the end, despite his government lobbying efforts and public disinformation campaigns, Edison was forced to capitulate. In 1893, Westinghouse was awarded the contract to light the Chicago World’s Fair, gaining all the positive publicity needed to make alternating current the industry standard.

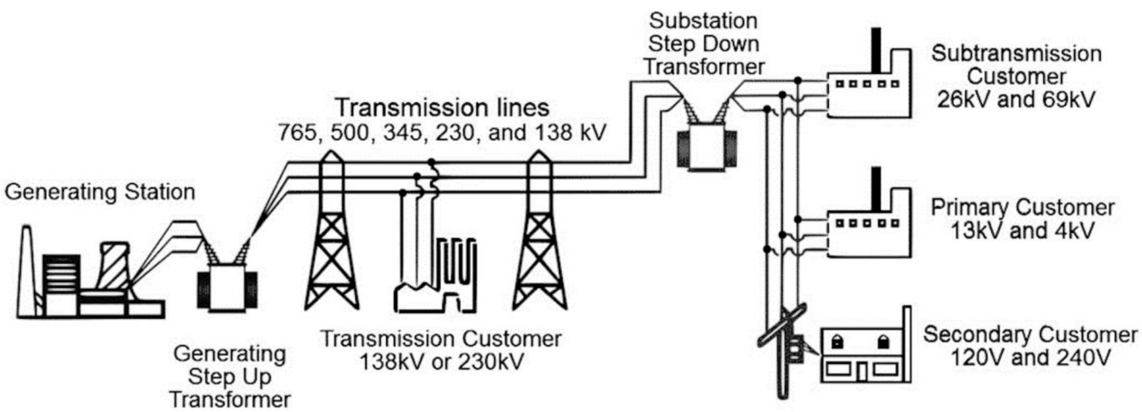
Edison later admitted that he regretted not taking Tesla’s advice.

So the lesson in all that is this. Should you find that you really take to this business of electronics, and come up with some really cool idea, and then decide to go into business for yourself, don’t make the mistake of thinking that your genius applies across the board — and especially not to marketing and public relations. That’s a mistake people with “engineering mentalities” too often make.

That was, in fact, my biggest failing — why I’ve wound up authoring this course on a frigid winter day up here in Michigan (13°F outside this morning), instead of spending my declining years on my own private island somewhere in the warmer climes.

Why AC Won

The other lesson is that AC won out over DC because it was much more transmissible.



With this scheme, a transformer is used at the generating station to step up the voltage to as high as 765,000-volts (765kV) for transmission purposes. That is then stepped down by transformers as needed at the user destination.

Residential distribution lines on wooden power poles usually carry 12,000-volts. The transformer on the pole has a 50:1 step-down ratio, which converts that to the 240-volt, single-phase, three-wire power connected to your house — two “hot” wires and a ground (earth). The 240-volt potential can be used for your high-wattage appliances, such as your electric range and electric clothes drier. A 120-volt potential is available from either of those two wires to ground, and is distributed in a balanced way to your lights and receptacles.

Suppose that at some particular instant your home is drawing 50-amps from this system. Since the step-up/step-down ratio is equal but opposite for current and voltage in the system, if the transmission line potential is 765kV, the ratio between that and your 240-volt household power is about 3200:1.

So your part of the load on the high-voltage transmission line at that moment would be only about 16mA!

Alternating Energy

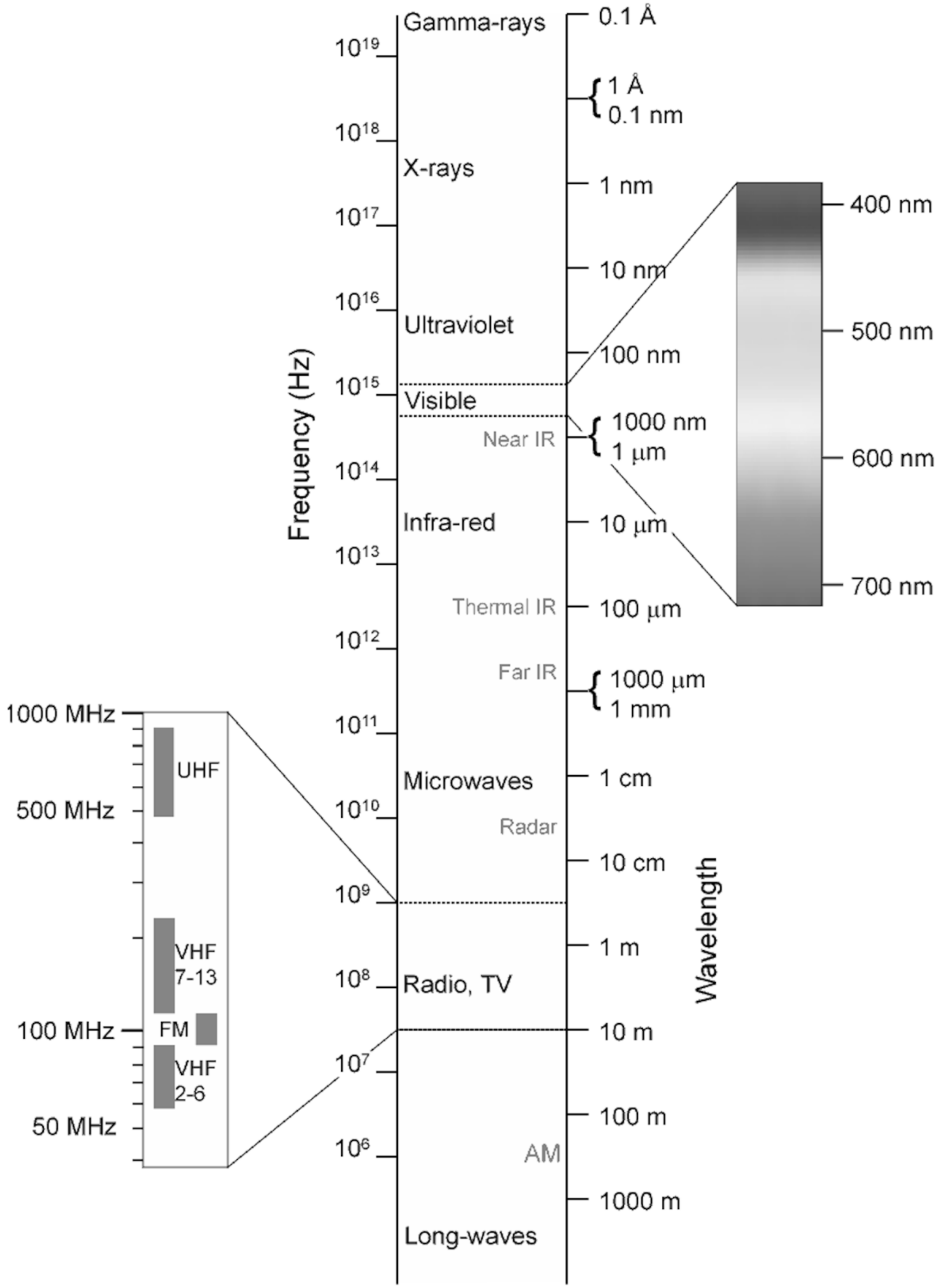
Before we continue this discussion, we should understand that alternating forms of energy are not limited to electric power systems.

For example, what we perceive as sound is mechanical vibrations transmitted through anything other than a vacuum in the form of alternating pressure waves, varying in frequency from 20 to 20,000 cycles per second.

This sort of energy travels through air at a speed of approximately 1,126 feet (343 meters) per second. It can consist of bursts of alternating energy or a continuous train of alternating energy waves.

These pressure waves can convey a variety of useful information, and most life forms have therefore evolved sensors capable of detecting them, and brain functions capable of interpreting them.

Alternating energy is found everywhere in nature — mechanical, electrical, and electromagnetic — with frequencies ranging from just about zero to near infinite, and with important electrical and electronic applications occurring over the entire range.



Frequency (Hz)
Wavelength
Gamma-rays
0.1 Å
10^19
1 Å
0.1 nm
10^18
X-rays
1 nm
10^17
10 nm
10^16
Ultraviolet
100 nm
10^15
Visible
1000 nm
1 µm
Near IR
10^14
Infra-red
10 µm
10^13
Thermal IR
100 µm
10^12
Far IR
1000 µm
1 mm
10^11
Microwaves
1 cm
10^10
Radar
10 cm
10^9
1 m
10^8
Radio, TV
10 m
10^7
100 m
10^6
AM
1000 m
Long-waves
400 nm
500 nm
600 nm
700 nm
1000 MHz
UHF
500 MHz
VHF
7-13
100 MHz
FM
VHF
2-6
50 MHz

From this point forward, when we're talking about electricity, we'll usually refer to the alternating energy as "AC".

Otherwise, getting into the vernacular of electronics, we'll just get into the habit of referring to alternating voltage forms as a *signal* — a throwback to the days when electronics was mainly just about radio.

Having established that, now let's look at the nature of AC electricity a little more closely.
