IV

ALTERNATING VS. DIRECT CURRENT

Alternating Current (AC) means that the current changes continuously through time. This is different than Direct Current (DC), which typically stays constant over time or varies with discrete changes. Devices like your laptop use DC power, which is part of the reason for that little brick of electronics that is at the end of your charging cable - you have to convert the AC power that the grid/buildings supply into DC power that your laptop uses. In the grid, things like solar panels generate DC power, but this has to be converted into AC because the grid uses AC - hence the need for *inverters*, which convert this DC into AC (and do a lot of other useful stuff that I won't mention here).

The term "AC Power" may be slightly confusing at first. Like the terms "LED light" and "ATM Machine", which result in us saying silly things like "light emitting diode light" and "automated teller machine machine", "AC Power" has us saying "alternating current power." It's a bit silly because current is not the same thing as power, and in AC grids, both current *and* voltage are alternating. But we will give whomever came up with this term a pass, because current is the quantity that represents the actual carrying of electric charge throughout the wires. Just because a voltage is present, for example, does not mean there is power flow.

"Alternating" means that the value of the current and voltage change throughout time in a "sinusoidal" fashion (see the red line in Fig vi), versus "Direct" (see the blue line in Fig. vi).

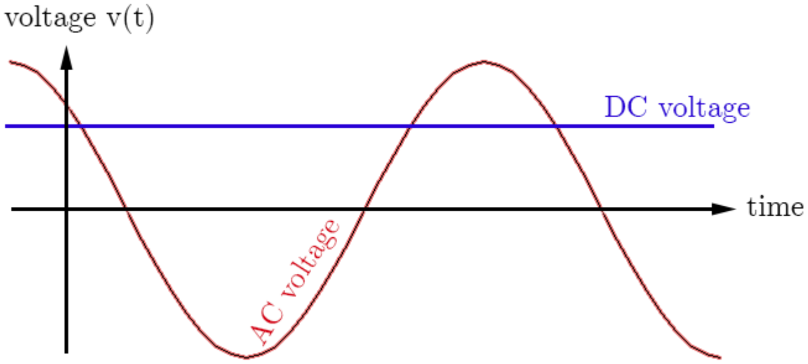

Fig. vi Alternating (red) versus direct (blue) voltages.

If AC currents and voltages vary throughout time, what does it mean when people say "the outlet in your house supplies 120 volts"? The 120 volts *is* an AC voltage, but it is actually something called the "root mean square," or RMS voltage. The RMS voltage is the level of AC voltage that would be equivalent to the voltage delivered by a DC source, assuming the same level of power supplied by both. See Fig. vi again, and assume these voltages are being supplied to something like a lightbulb. For the same amount of power consumed by the bulb, the DC source might be fixed at 120 V, and the AC source might vary from -170 V to 170 V.

When people say "That's a 138 kV transmission line," they're referring to this RMS quantity. The actual voltage through a 138 kV line can vary from -195 to 195 kV. We'll learn about how "negative" voltages and currents work, too, and how they still are able to deliver power to a load.

Root-Mean-Square (RMS). When we refer to AC voltages or currents as single numbers, we are talking about the RMS value of that sinusoid. The name comes from the fact that you *square* the voltage (or current), take the *mean* (average across the squared values), and square-*root* the result. We don't talk about the peak because the voltage is only at its peak for a fraction of a second. We don't talk about the time average, because the time average is close to zero (the positive parts of the sinusoid cancel out the negative parts when we average everything out). We use RMS because we care about the "effective" power delivered to a load. If we were using DC, this would be straightforward - we'd just talk about single values of voltage and current, not time-varying, and be done with it. The RMS values are thus derived from the equivalent power delivered by a DC source with that voltage and current.
The RMS value of a sinusoid is closely related to the peak of that sinusoid:

$$V_{peak} = \sqrt{2}V_{rms} \tag{2}$$

which is how I knew that the 120 V RMS voltage supplied to your house peaks at 170 V ($170 \approx \sqrt{2} \cdot 120$). The same relationship holds for any AC quantity.

As you may or may not remember from high school math (although high school was a helluva long time ago, and thank god for that am I right?), sine (and cosine) waves have a **amplitude**, **frequency**, and **phase shift**. All of these are important in order to understand the different types of power.

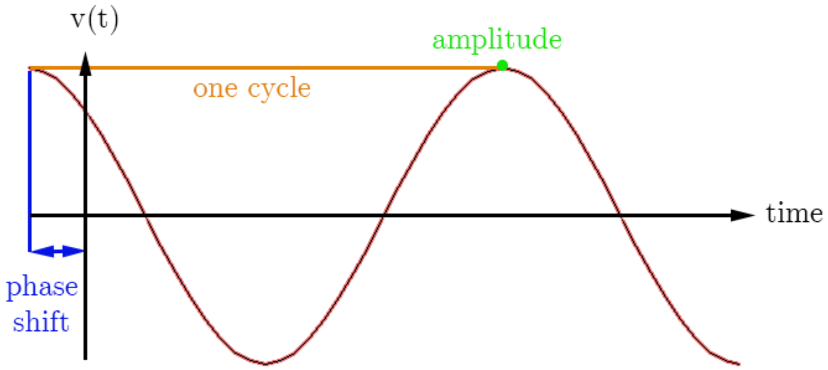

FIG. vii The three features that characterize a sinusoid: phase shift (its offset from the origin), frequency (how many cycles are completed in a second), and amplitude (the maximum value attained).

Amplitude: The peak that a sinusoid reaches. In the example we've been using so far of standard outlets in the U.S., this is that 170 V peak.

Frequency: How many cycles are completed in a second. In Fig. vii, one full cycle (plus extra) is completed - where the sinusoid returns back to the voltage that it started at and is continuing to move in the same direction (up or down) that it started the cycle at. The grid frequency in the U.S. is 60 Hertz (Hz), which means the voltage and current waveforms complete 60 cycles per second.

Phase shift: The sinusoid may not have its peak exactly at zero seconds. This offset is called the phase shift. It's not super important to know the phase shift of a single voltage or current waveform in practice because "time zero" is challenging to define - but the *relationship* of the phase shift between voltage and current is very important.

Sinusoid Characteristics. Mathematically, voltage (or current) at any point in time t can be written as a function of amplitude V_p, frequency f (in Hz, or cycles/second), and phase shift ϕ_v:

$$v\left(t\right) = V_p \cos\left(2\pi f + \phi_v\right) \tag{3}$$

This can be written as either a sine or cosine function, but I prefer cosine because it seems less aggressive to me, I dunno why.