Problems with AC Generation:

Max Voltage

\[ \Delta V_{\text{wire}} = I \times R_{\text{wire}} \]

Therefore you want to minimize the wire resistance and current as much as possible while still getting the same power across the wire. Since power equals voltage * current, you need to run a high voltage across the power lines to get minimum current and thereby get minimum losses.

Remember our equation for the voltage difference:

\[ \Delta V = 4 \times B \times A \times N \times f \]

“synchronous generation” \(\rightarrow\) generator follows what the engine does

This creates issues because the frequency of the rotor (which is tied to an engine) determines the frequency of your output voltage.
We ask the engine: no matter how much power you put out, rotate at the same speed.

Electrical frequency is 60 Hz; change to revolutions/min (rpm)

\[ 60 \text{ Hz} = 3600 \text{ rpm} \]

The engine must rotate at this speed to generate the appropriate frequency.

Diurnal variation is power is a big factor

More power is used in the day than at nighttime

Air conditioners also make a difference

Only sharp changes in generation are a result of component failure. This is one way you get blackouts

What if your generator doesn't run at the right speed?:

Options for rotating faster:

Gears is about all you can do (not direct drive)

Options for rotating slower:

Gears again

Add more magnetic poles. This will reverse the magnetic field not every revolution, but every fraction of every revolution.

AC vs. DC power:

Why do we want AC power?:

You can transform AC power and then transmit it over long distances

Transmit power \( P = \text{total current flowing} \times \text{voltage drop} \)

\[ P = I \times V \]
Wire voltage loss:

I the same because charges don’t disappear

Power burnt in wire = $I_{wire} \cdot \Delta V_{wire}$

High current means high losses

$P_{wire} = I^2 \cdot R_{wire}$

$P_{wire} = \frac{P_{total}^2}{V_{total}} \cdot R_w$

Therefore the lower the voltage transmitted, the larger the power losses in the wires.

You want to transmit at very high voltages and AC allows you to transform to higher voltages.

AC is easy to move because you can transform easier (there are transformers outside of your house to get to step down the voltage to a useable level.

![Transformer Diagram](image-url)
A wire from your voltage lines wraps around the ferromagnetic material on one side, and by Ampere’s Law this generates a B-field in the ferromagnet.

The B-field will oscillate because you are using AC power

This coil will have huge voltage and low current since you have low resistive losses with higher voltage

Another coil wraps around the other side, and the oscillating B-field passing through it, creating a current.

You can determine the voltage that is generated in this wire by changing the number of coils you wrap around the ferromagnet

You want to get a low voltage and higher current out so that it is safe to use in your home (you don’t care about resistive losses because you aren’t traveling very far to the house).

**Three-Phase Power:**

![3-Phase Power Diagram](image)

Coils on the stator are offset from each other creating 3 sine waves that are out of phase. Number of coils must be in multiples of three to get this 3-phase power.

The average voltage is then zero and you get maximum transmission for the minimum amount of wire.
Electricity Generation 2 Slides:

First commercial generating stations

Used reciprocating engines rotating 2000 rpm (33Hz)

Generators were turned with belt drives (full of losses)

The frequency didn’t matter too much because each grid was separate and the electricity was used mostly for lighting.

This wasn’t regulated until the 1940s

Edison v. Tesla:

Edison wanted DC power

His company was General Electric

First steam-powered electricity and electric utility in 1882

This required many small stations because transmission losses were high.

PR stunt: He made the AC electric chair to prove AC could kill you.

Tesla wanted AC power

His company was Westinghouse Electric Co. founded in 1886

Did long distance transmission of hydropower at Niagara Falls to factories in Buffalo in 1895. This was transmitted at 25 Hz

PR stunt: Lit the World’s Fair in Chicago 1893

Steam Turbine:
Parson’s steam turbine invented in 1884 and it makes 80% of the world’s electricity today.

The power growth and efficiency gain was rapid.

They were more efficient and simpler than reciprocating engines as long as you are going a steady speed. Therefore, we don’t use them in our cars. However, they are used on military ships

Technology Stasis:

Generators have hardly changed in 100 years.

They are still big because it is easier to get the cooling system to work

Steam turbines have also stayed relatively the same 100 years

There are many rows of blades to dissipate the energy of the steam slowly over these rows to maintain reasonable speeds. The pressure gradually drops over the series of fan blades.

Small blades are for high pressure and big blades are used for low pressure

Modern Electricity Production:

Haven’t talked about the condenser and compressor.

The used steam is condensed with cooling water in separate pipes because their water for steam is very pure and can’t be wasted.

This condensing also creates a small vacuum for extra power (like a Newcomen engine)

Compressor pressurizes the water.
Also have a transformer for getting the voltage to be the right level for the grid

There are multiple stages to achieve steam turbine efficiency (including a reheat stage for higher efficiency)

Gas turbines

Operate on the Brayton Cycle

Internal combustion in air

Waste hot air can then be used to heat steam for a steam turbine.