**What's Watt? - Penguicon, 2017 - Southfield, Michigan**

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50-minute presentation on gaining a simple understanding of DC and AC power.

## 1) Introduction

Water and Electricity - we're made of both, but most people only understand water.
Similarities between them will let me teach by analogy - but analogy has limits.
Hope to get from static/current electricity through units of measure,
production and storage of electricity, DC and AC power and their uses, and
how modern technology is blurring the lines between them.

## 2) First analogies

Static Electricity - water in a bucket on a door - fill the bucket with cups, it overbalances.
Current Electricity - fill the bucket with a hose, it overfills, pours continuously out.
Voltage - similar to water pressure. Higher pressure needs thicker hoses (thicker insulation).
Current - (Amps) Area of oncoming water (width x depth of a river, or diameter
of a full water pipe) Larger current (more Amps) needs bigger pipes (wires)
Wattage - Horsepower, GPM. Measure of strength - "Power"
Energy - How much work got done, has a time component. Watt-Hour -> Gallon

Note about getting heat from electricity and heat from water, and how heat may not be what we're trying to achieve with electricity. Using resistance to drop voltage creates heat, which can cause thermal problems and is inefficient.

## 3) DC and AC

DC - Direct Current, water in a pipe or hose, water flowing down a river.
AC - Alternating Current, ocean waves hitting a beach.

Getting work out of DC - it's moving in a constant line, so you can either move with the flow (like a boat) or you need to keep connecting and disconnecting, like a mill-wheel. DC winds up being related to rotation.

Getting work out of AC - it's like ocean waves, so you can get work in two ways, from the water pushing back and forth (saw), or from the waves moving up and down (pump handle.) The second is "Transformative".

## 4) Generation and Storage

Generator = Pump - taking one kind of energy to produce another.
Battery = Water tower or Reservoir - takes energy to move water into storage.

DC power can be stored, AC cannot - once it's stopped in storage, it comes back out as DC.

AC power can be transformed, DC cannot. It's the motion of the waves which allow the conversion. Physical power storage can run an AC generator.

**5) Power Sources**
Power supplies - need to have DC voltage _and polarity_ which matches your equipment. Amperage of supply needs to be _more_ than the device requires.

Edison plugs are polarized to set voltage and maximum supply amperage.

Wattage - volts times amps, amount of raw power that's available,
think "Horsepower" - it's actually directly convertible. (1 HP = 745.7 Watts)

**6) AC Power - Phases**
DC generator - magnet inside of a coil. Tesla - move the coil to the top of the magnet, and you get a sine wave output. Problem with motors, because motors don't know which way to turn - there's no "polarity", it alternates.
Single phase motors need tricks to force them to start turning one way.

New unit - "Hertz" - Cycles per Second - same as in sound,
440Hz = A below Middle C.
60 Hz versus 50 Hz - Europe uses 50, US uses 60, mostly historic reasons.

Add two more coils, now there's three sine waves which have a lead/follow arrangement. Hook two gens together, and one shaft tries to follow the other.
Swap any two of the three leads to reverse direction.
AC motors run at speed controlled by the power company (AC powered clocks)
DC motors run at speed controlled by the voltage, and a direction from polarity.

**7) Power Control**
Edison Effect - trying to stop light bulbs from darkening, add a plate to catch the metal, created a device which only lets current flow one way.
Add another element, now can control a large current flow with a small current - that's a way to dim lights without making extra heat.
Trouble is it needs a hot filament, takes large amounts of power - needs wall power to run it, difficult and expensive to make portable. (90, 45, and 1.5 Volt batteries).

Tubes = Valves (British name for them, as well) Can use tubes to create waveforms, to switch signals on and off, to amplify sounds and other signals.
Birth of radio, television, and higher speed computing (faster than relays).

**8) Transformation**
Edison's DC distribution had problems with loss of voltage in transmission lines. DC power's voltage could only be increased with a motor-generator combination. The analogy is how you can't boost the water pressure in your house without adding a pump. The story is that AC power doesn't lose voltage in long transmission lines - that's totally untrue, the actual answer is that it loses more, but voltage can be boosted without requiring moving parts.

Transformative motion - ocean waves running a pump handle, it's not being driven by the water moving, but by the change in water depth.
Build a transformer right here - electrical power to magnetic coil to paper cone, transforms to air pressure waves, which transform to mechanical motion at the eardrum, which transform to pressure waves in water, which trigger electrical impulses in nerves which transfer to the brain.

Electrical transformers - coil to magnetism to metal (magnetic storage) to coil.
Electrical isolation - if coils are different lengths, then voltage between the two coils is different. 50 Hz transformers need more metal than 60 Hz, because there's more magnetism to store between wave peaks.

**9) Square waves to make Sine Waves**
Invention of the transistor - solid state, low power version of the vacuum tube.
Allowed radios to go from table sized and wall power to tiny and run from 9V.

Transistor can be used as a switch - more efficient, less heat.
Pulsing DC in a square wave can drive a transformer. Early UPS units would use square waves to feed a transformer and make square wave 120 Volts. Pulse DC faster, and you can dim a light without making extra heat - change the width of the "On" pulse to dim or brighten. Go even faster, and you can dim/brighten in a sine wave - make "real" AC out of DC, at any frequency - variable speed AC motor (drill motor).

As you go faster, transformers need less metal. Go fast enough, the transformer can get really, really small. Common devices use both AC and DC, switching back and forth many times. Modern wall-warts still have transformers, but tiny. PC motherboard can have dozens of conversions onboard.

Go even faster, and you can model any waveform - 2000 Hz works well for making 60HZ waveforms, 250,000 Hz is enough to model audio - make an amplifier with almost no heat dissipation.

**10) Q&A**