Electrical energy, explained

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Basics & safety

Disclaimers:

We are only looking at sine-form AC power and constant-form DC power today

Mainly a German perspective

What is electricity?

- Electrons around atoms
  - When they “flow” think less of a high-speed fluid and more of a stick being pushed
- Purest form of energy known to humanity
  - Heat is the least valuable form or energy, it’s pure entropy
- Datacenters are large heaters
  - Most of the energy is used on heating, not on information
  - ...and then more energy used for cooling
  - ...and reclaiming this heat energy without subsidies is super hard

Classification

- IEC voltage ranges
  - High voltage: >1000 VAC, 1500 VDC
  - Low voltage: 50-1000 VAC, 120-1500 VDC
  - Extra-low voltage: < 50 VAC, 120 VDC
- Informal ranges
  - Highest voltage: 220 kV - 1.5 MV (yes, really)
  - High voltage: 52-220 kV
  - Medium voltage: 1000 VAC / 1500 VDC to those 52-100 kV

Why those specific ranges?

- High voltage arcs
  - Arcing in a medium voltage system can throw you several meters
- Low voltage shocks
  - Your muscles cramp, and you can’t let go
- Extra-low voltage carries
  - You can lick 25 VAC or 60 VDC (disclaimer: don’t actually do this)
- Heart attacks are boring
  - Your clothes can catch fire
  - You can explode explode

Safety, cont.

- Grossly oversimplified: “Volts transmit, amps kill”
- Batteries are “more dangerous” because their safety needs more headroom
  - A former co-worker, a fully trained electrician, welded an Alixboard to a POP rack
  - Stick welding is literally “low volts, high amps”

If someone is stuck, in a pinch, use a wooden broomstick or kick them hard

Wat Watt?

In AC

Watt

- Volt * Ampere = Watt

Watt

- ~~Volt * Ampere = Watt~~
- Volt * Ampere = Volt-ampere
- Volt-ampere * cos(phi) = Watt
- In SI units: 1 VA = 1 V * 1 A = 1 W
- So, Volt * Ampere = Watt, sometimes

I am not joking

Watt?

- Real power: Doing actual work, measured in Watt
- Apparent power: Put into the system, measured in Volt-ampere
- Idle power: Does not do useful work, measured in IPv6

- Germany:
  - Low voltage billing: in Watt
  - Medium/high voltage billing: In VA
  - Datacenter billing: They try really hard to sell in VA

I pay the power!

- Negative argument:
  - DCs are billed in VA because VA is always at least as much as Watt, so more mony for datacenter providers
- Positive argument:
  - If apparent power needs to be on the wire, all infra needs to be sized for it. The apparent power, not the real power, needs to “fit” into your infra
  - Power distribution is a significant part of CapEx, power usage the main component of OpEx

The truth is somewhere in the middle

I pay the power?

- Positive argument:
  - DCs themselves are billed in VA and they need to cover their costs
- Negative argument:
  - Depending on P(W)UE, 20%-100+% of the overall energy consumption is from the DC itself, they select the units
  - You can compensate idle power, make it go away

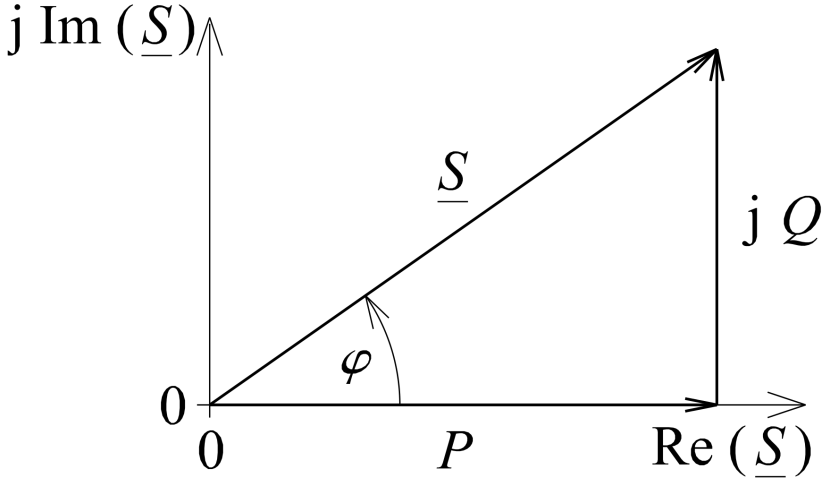
So how can you compensate?

How can people compensate?

With a fast, large, and loud car

How can you compensate?

- Both voltage (Volt) and current (Ampere) have a sine wave
  - If the waves are aligned, VA == Watt
  - If the waves shift against each other, you get idle power
- S * cos(φ) = P

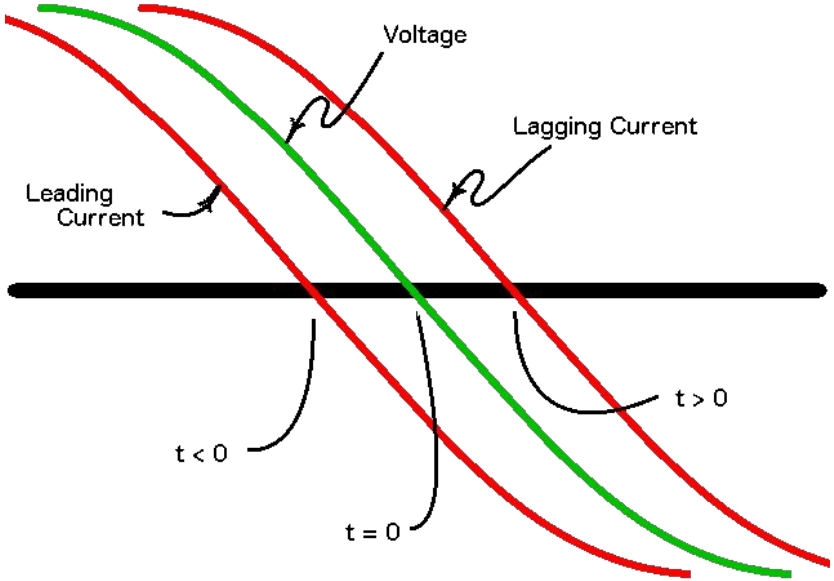


How can it shift!

- Resistive load: No shift
- Capacitive loads: Current leads voltage
- Inductive loads: Current lags voltage
- Datacenters have mostly capacitive loads, so UPS often have inductive elements to compensate idle load
  - Compensator needs to “charge” itself
  - Only CapEx cost, no OpEx!

Bonus slide for confusion

- Leading/lagging current is measured in degrees; 90 degrees max
- Look at “leading” and “lagging” here...



Bonus slide for comprehension

- Switching power supplies have supercaps, and they have a **capacity** they need to fill to function
- Coils **induce** a magnetic field
- Cables hold charge
  - Low voltage: No one cares, just pop the circuit breaker
  - High voltage: Needs to short to ground, or a cable which is “off” can kill

All of this was for AC only, DC does not have that problem

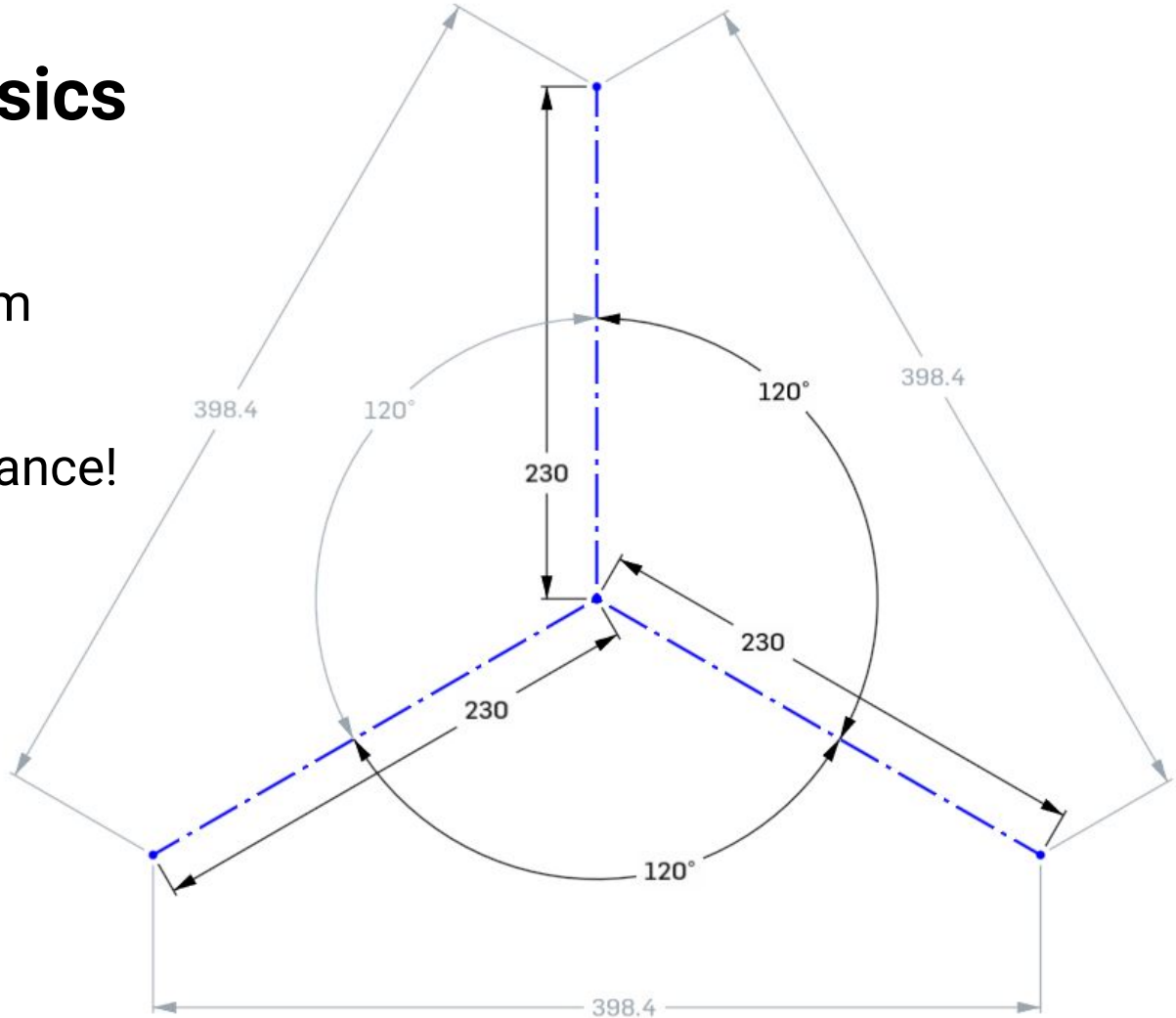
More geometry

Medium voltage

- Three phase power
- Star point created locally

Geometry & physics

- 3 * 230 V = 400V
- Three phase system
- “Star point”
- It’s literally the distance!



Bonus! (time)

- Selectivity: When does which breaker pop
- Why do you need minimum distance between large wires?
- How do you get a blacked-out datacenter back online after a complete power outage, just from diesel gensets?
- Failover A+B -> A -> Load higher -> Pops the circuit

Thanks!
Questions?
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