Bijli → Electricity

Current, voltage, power

Generation

- The whole game is "spinning the turbine" in most cases except solar power.

- Thermal power stations

  - Coal, natural gas ↓ burning
  - Nuclear ↓ nuclear fission

  ⇒ Chemical/nuclear energy → Thermal energy (steam) → Mechanical energy (spinning turbine) → electrical energy

- Water (hydroelectric)

  ⇒ Potential energy (stored water) → Kinetic energy (flowing water) → . . . . . → . .

- Wind

  ⇒ Kinetic (wind) → . . . → . . . .

What does exactly turning the turbine do?

Turbine is connected to a generator. Spinning turbine rotates a magnet within a coil of wire ⇒ creates magnetic field making electrons in wire to move ⇒ electric current

Electromagnetic induction.

Solar - Photovoltaic effect - Panels are made of semiconductor materials (silicon), Knock the electrons loose when struck by sunlight, which is electric current, direct flow of electrons. Hence no need of a turbine.

Transmission

Now that generation is happening how do you make it reach people's homes?

Wires used for transmission ⇒ conductors but still don't get 100% electricity reaching destination due to resistance, converts electricty to heat.

Transformers at power plants

$P = VI$, now with <u>high voltage</u>, the current flowing is lesser leading to lesser wastage due to resistance

Power

$P_{wastage}$ $P_{loss} = I^2 R$ ↓current less power loss

due to heat

Transmission towers hence exist for different voltages, I remember seeing of different shapes & sizes along expressways and thinking "why?". Now I know.

Three-phase circuits - multiple

Shield wires - non-energized line to deal with lightning.

The book has great diagrams.

Transmission Line Components

- Conductors - Aluminium strands
- Insulation - Thats done via insulator strings connecting conductors with air gaps providing insulation
  - x Rubber/plastic usuage would make it very expensive to get insulation.
- Corona discharge - Effect created by ionization of air surrounding the conductors. Dewy morning, stormy weather, high altitudes low atmospheric pressure you can hear sizzling sound.
- Skin effect - AC travels mostly around the surface of the conductor rather than evenly through the full area.

To combat this each phase is sometimes run as bundle of smaller conductors separated by 'spasers", increases surface area and overall

large diameter of bundle reduces corona discharg.
spread over (electric field)

Corona rings help similarly.

Dampers - To absorb wind energy and reduce long-term damage to wires.

Substations

Now this reaches a commonplace from where it can reach homes, needed to mainly step-down high voltages. Plus monitoring grid's performance, protection against faults.

Transmission Lines — Power transformer (Step-down) $\xrightarrow{\text{out}}$ Feeders: individual circuits, own circuit breaker

control building - relays, operating equipment and some circuit breakers. To guard from weather.

Static poles, lightning rods to guard from lightning by grounding.

Arresters - Connected to energized, start conducting when spike in voltage, excess electricity into earth.

Ground grid - Fault or short circuit, this is used to sink lots of current, trip the breakers via the relay detecting the surge.

Also since its connected to everything within the substation, it can make everything to be at same voltage - equipotential. Electricity flows only when there is difference in potential, hence touching any equipment doesn't make electricity to pass through a person.

at same voltage potentially quite high person and substation equipment

Substation Equipment

- Power transformer - Main thing $\Rightarrow$ step down voltage via electromagnetism. Adjacent coil $\Rightarrow$ voltage out $\propto$ no. of loops in coil

- Radiators - Fans, heatsinks $\Rightarrow$ heat dissipation and help keep oil and components cool.

- Circuit breakers - For lower voltages, located in a sealed container under VACUUM to avoid electricity conducting in the air betweens contacts. For
arcs
higher voltage, breakers are often submerged in tanks filled with non-conductive OIL or dense gas $\Rightarrow$ SF_6 $\Rightarrow$ sulfur hexafluoride.

- Instrument transformers - So this was confusing me, not what it does but more like the location of it in the diagram. I was thinking ki agar step-down voltage this is doing what's role of power transformer. Thoda research and AI se to and fro questions cleared stuff for me.

To clarify my first doubt the main line goes unaffected through to next equipment in flow, the CT (current), PT (potential) just take a fraction of the thing to measure post transforming lower current and voltage, that wire is called "signal wires" go to control room.

CT ⇒ measures by being in series (rate of flow)
PT ⇒ in parallel, between two points. electromagnetic induction same principle like power transformer.

Utility Pole

- Primary distribution conductors (lines)
- Distribution transformers - To step down voltage to the level useful in homes.

11kV → 3 phases wire , neutral wire
↓ 415V ↓ 0V

Single-phase for home ⇒ 230V

- Protection device - fused-cutout ⇒ circuit breaker and isolation

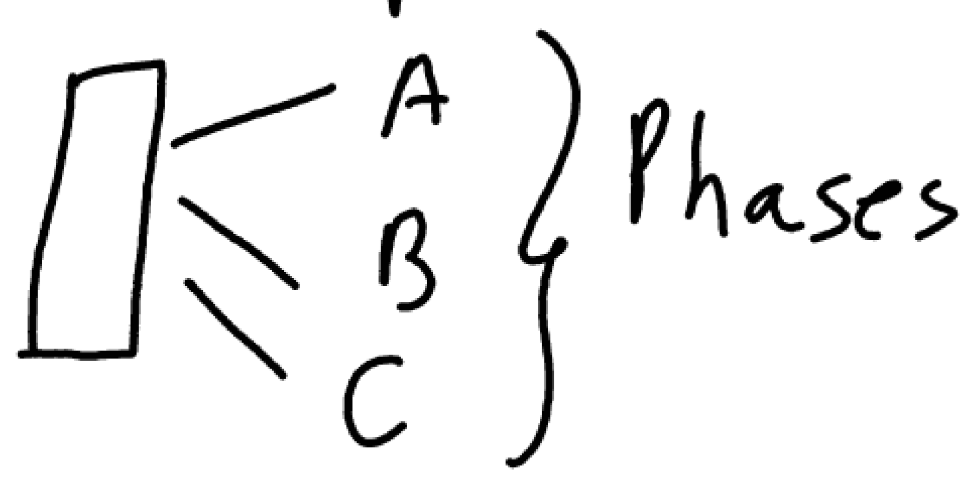
Nowadays lot of the distribution happens underground and the utility poles have vanished.

⇒ "Electrical Grid"

I found reading this chapter of the book ⇒ "Engineering in Plain Sight" really thought provoking, made me jump into stuff more to understand better.

AC => Alternating current

Power plant



electromagnetic induction from movement of coils inducing voltage in the three phases.

Each phase is offset by 120°, it follows a sine function. So at each point together the three phases have net current as zero.

These phases are transmitted over the transmission lines reaches substation, voltage is stepped down and then different phases go to different regions.

Now when there is surge due to fault or anything, the net current is no longer zero. The excess current uses the netutral line to go back to the substation power transformer, where its grounded

The above happens also because of imbalance within various phases power requirments.

Flipping on the switch in my home -

- Electrons in the wire start vibrating - push and pull (direction change), become static (when fn passes through 0), that "heat" is electrical resistance

- The electrons vibrate because flipping the switch completes the circuit from the substation power transformer to the home switch, this makes the energy stored in the electric field be released. The field already existed within the wire, waiting to be used. Energy flows from high to low voltage, hence this happens.

- Magnetic field ⇒ moving of electrons, this combines with electrical to form electromagnetic field. This is used to transport energy to appliance.

- The combination of the "pressure" from electrical field and 'movement' => magnetic field => creates flow of energy => "Poynting vector"
- It shows energy flows in a direction perpendicular to both electric and magnetic fields. This wave of energy is what travels along the outside of the wire and delivers power to your appliance.