ELECTRICAL SYSTEMS AROUND US

Unit 1

Introductory Words

- Electrical System Components
  - Light bulb, Socket , switch, Wire to switch, Wire to circuit box, Circuit breaker, Watthourmeter, Connection to distribution system, Distribution transformer, Distribution system, Substation, Capacitors, Disconnects, Subtransmission system, Tap changers, Current transformers, Potential transformers, Protective relays,Metal-oxide varistors, Transmission system, Suspension insulators, Generators etc.
- Non-Electrical Components
  - Glass for bulbs, Circuit box, Poles for overhead lines, Transmission towers, Plastics for capacitor insulation, Fiber optics for communications, Foundations for substation equipment, Ceramics and polymers for suspension insulators, Oil for transformers and circuit breakers, Springs for circuit breakers, Process control for component manufacturing, Computers for process control, Computers for generation control and dispatch, Turbines for generator, Coal for making steam to turn turbine etc.

Electrical System

- Why take Electrical Engineering?
  - Like computer literacy, electrical literacy is very important to engineering and everyday life
  - So many things are powered or controlled by electricity
  - It is used to communicate by video, wireless, phone or data
- So many physical phenomena are measured using sensors (devices that convert a physical phenomena into an electrical signal), or more generally with transducers (devices that convert a signal in one form of energy to another form of energy)

Why Electrical Engineers?

There are many challenges in facing the world for sustainable and enhanced quality of life:

- Transportation
- Energy
- Communication
- Medicine
- Housing

Electrical system engineers are needed for creating electrical and electronic solutions to these challenges!

What is Electricity?

- Electricity is energy transported by the motion of electrons
  - We do not make electricity, we CONVERT other energy sources into electrical energy
- Non-thermal conversion
  - Source to electrical (sun, chemical)
  - Source to potential/kinetic to mechanical to electrical (dam, tides, wind)
- Thermal conversion
  - Heat to mechanical to electrical (geothermal)
  - Stored energy to heat to mechanical to electrical (fuel, sun)

Electricity and You

- Your body operates on electrical impulses from your brain that travel along your nerves.
- It does not take much electrical energy to interrupt these electrical messages
- What do you think would happen to you if the messages from your brain to your heart/ lungs are interrupted?
- 100 milliamps (0.1 amps) of current is more than enough to kill you.

How to Avoid Injury?

- Generally, electricity takes the easiest path to ground
- One way to protect yourself is to take steps to insulate yourself from ground
  - Rubber soled shoes
  - Avoid damp areas
  - Always power down
  - Work with one hand

Electricity - Uses

- Lighting, heating, cooling and other domestic electrical appliances used in home.
- Street lighting, flood lighting of sporting arena, office building lighting, powering PCs etc.
- Irrigating vast agricultural lands using pumps and operating cold storages for various agricultural products.
- Running motors, furnaces of various kinds, in industries.
- Running locomotives (electric trains) of railways.

Wall Electricity

- Most common electrical appliances operate on 120 VAC or 240 VAC
- The circuits these appliances operate on can range from 15 to 50 amps depending on the fuses/ circuit breakers they are wired to
- These protective devices are not designed to protect you, but rather protect the electrical system in your home
- GFCI (ground fault circuit interrupter) breakers and outlets are designed to protect you in the case of severe/ fatal electrocution by sensing any current not traveling through the hot or neutral wires

Energy Crisis?

- Non-renewable energy sources set to expire
- Need renewable alternatives
  - Solar
  - Wind
  - Geothermal and Hydroelectric
  - Nuclear
- ~ 70 % of power generating capacity in India is from coal based thermal power plants.

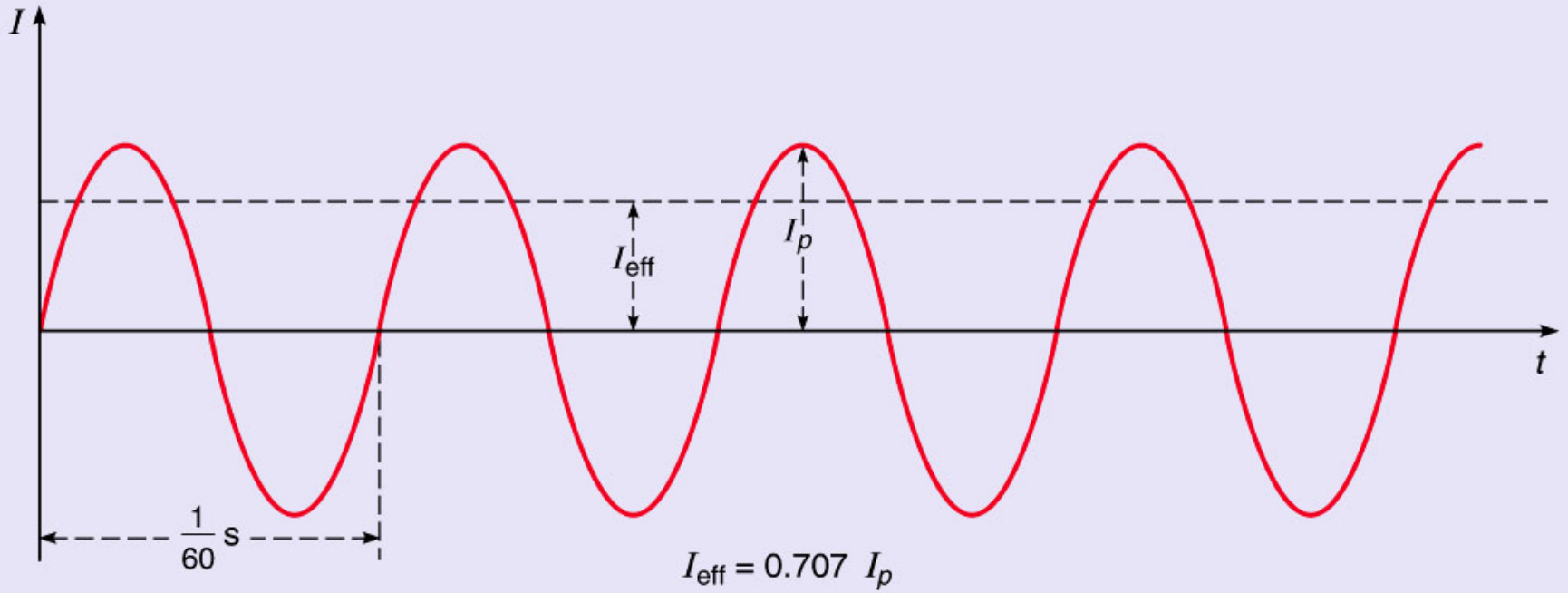
Applications

- AC Applications
  - Hospitals
  - Hotels
  - Residence use
  - Power plants
  - Military applications
  - Isolated rural areas
- DC Applications
  - Space vehicles
  - Underwater vehicles (submarines)
  - Space Station Transportation
  - Public transportation
  - Personal vehicles(Zero emission Vehicles)
  - Commercial and Military vehicles

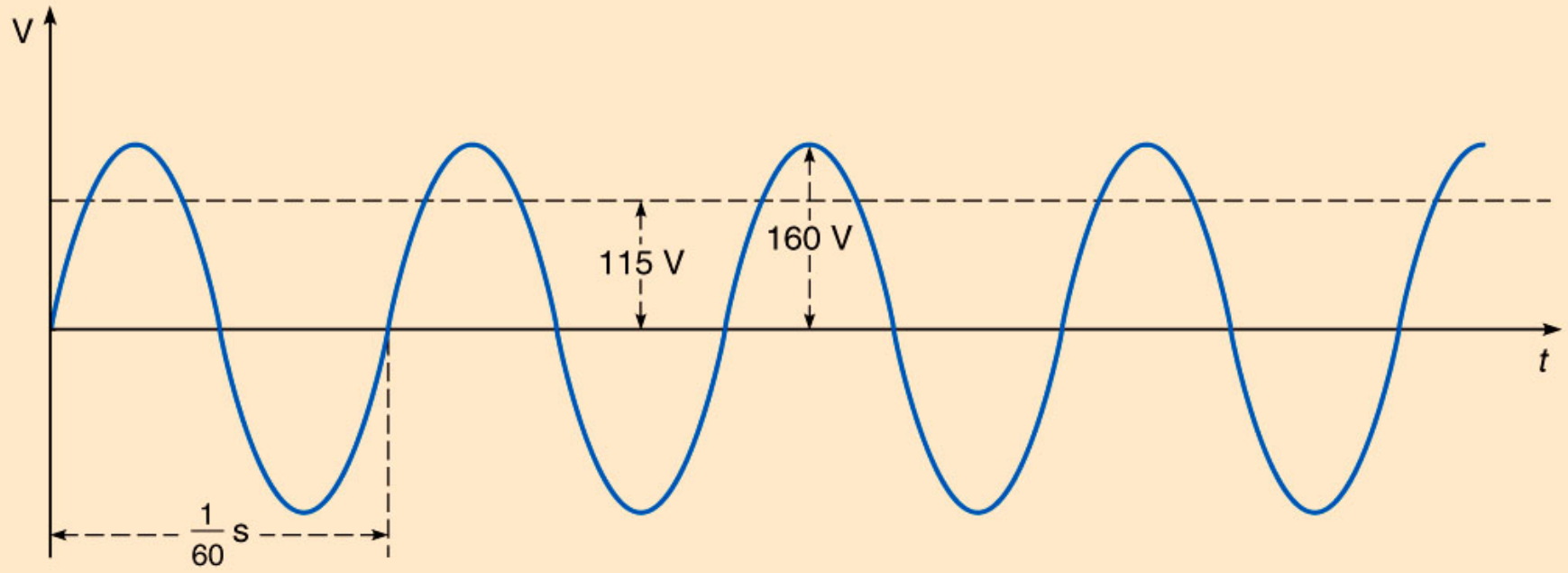
AC and DC Power

- Alternating Current power where the current and voltage varies sinusoidally with time
  - AC power is easier to distribute
  - Generators provide AC power.
  - AC voltage from a generator can be stepped up or down by a transformer.
  - AC is used for most machinery, lights and appliances
- Direct Current power doesn't vary with time
  - Used to power electronics
  - Easier to store (batteries)
  - Useful when off the power grid

Alternating Current



Alternating Voltage



Effective voltage = 115 V

Difference Between Power and Energy

- **Power * Time = Energy**
- **Power is the rate of using energy.**

- Forms of energy
  - Radiant
  - Electrical
  - Chemical
  - Sound
  - Thermal
  - Nuclear
  - Magnetic

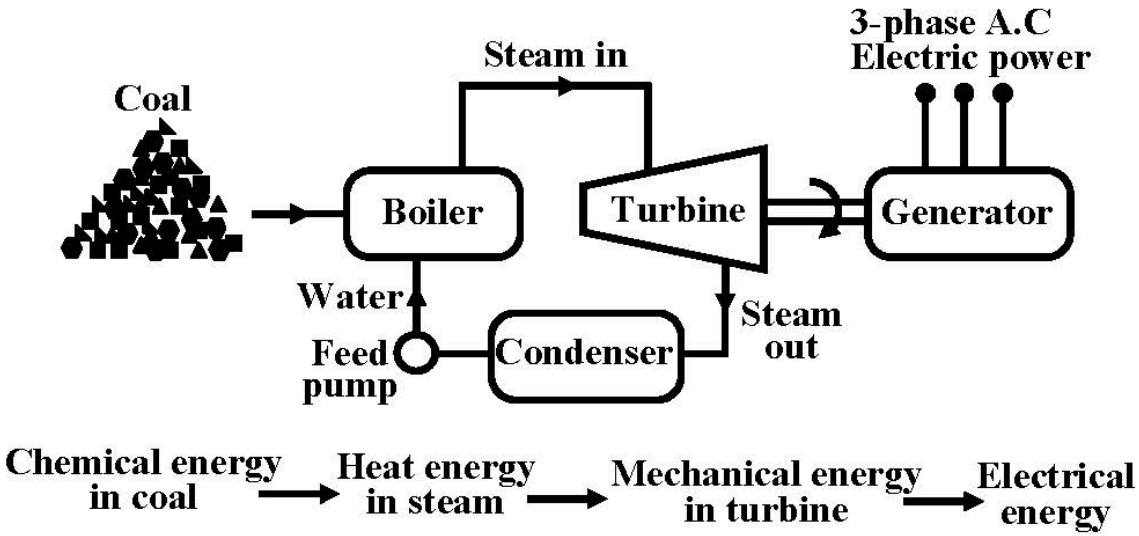
Power Plant

Generation

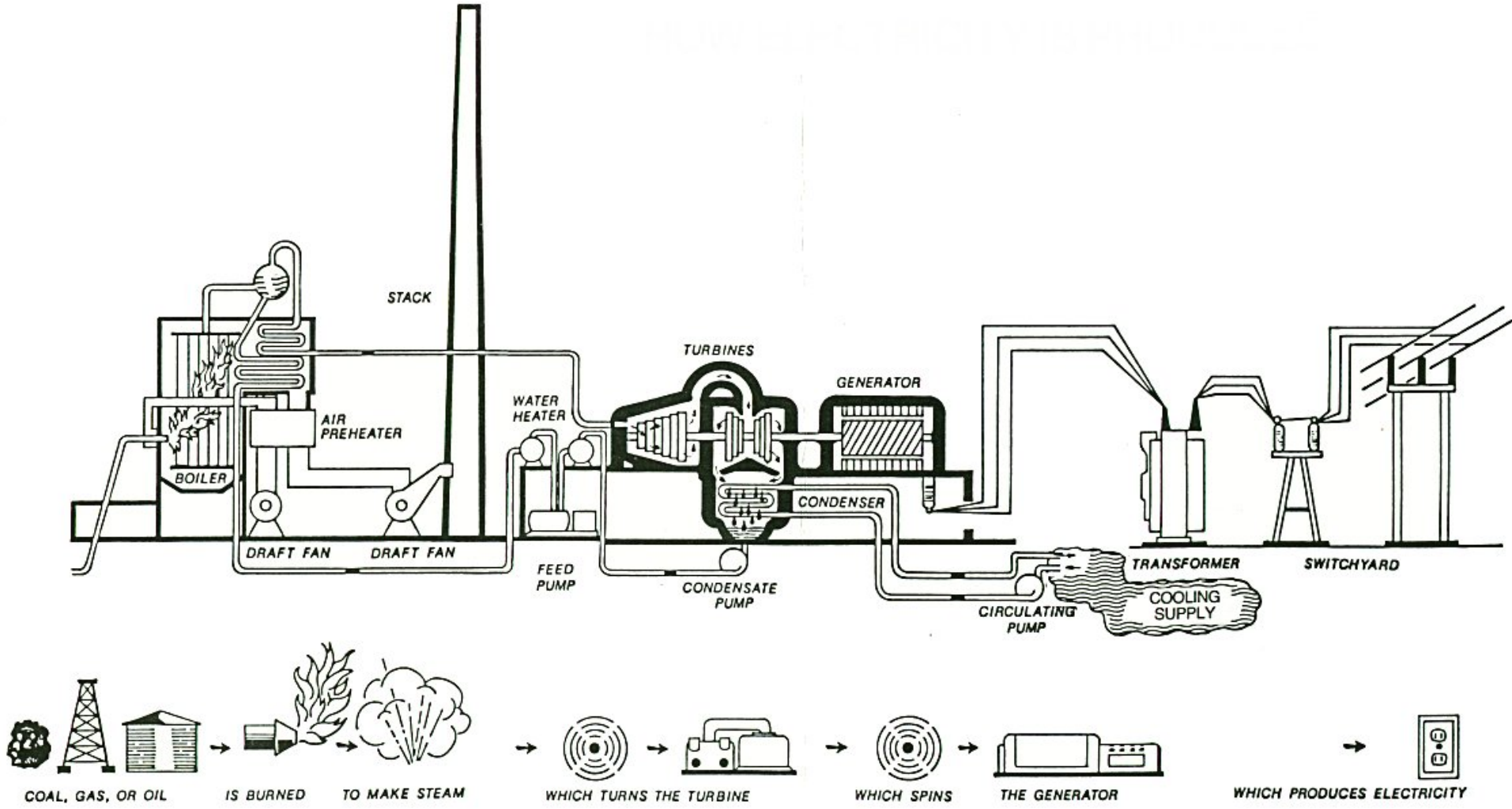
- First DC Generators
  - Limited to few hundred volts
  - Large currents needed => big copper cables
- AC Systems in 19th century
  - Transformers
  - Nicola Tesla in favor of AC motors
  - 3-phase at 50 Hz alternators

Power Plants

- Thermal
  - ✘ Non-renewable
  - ✘ Pollution



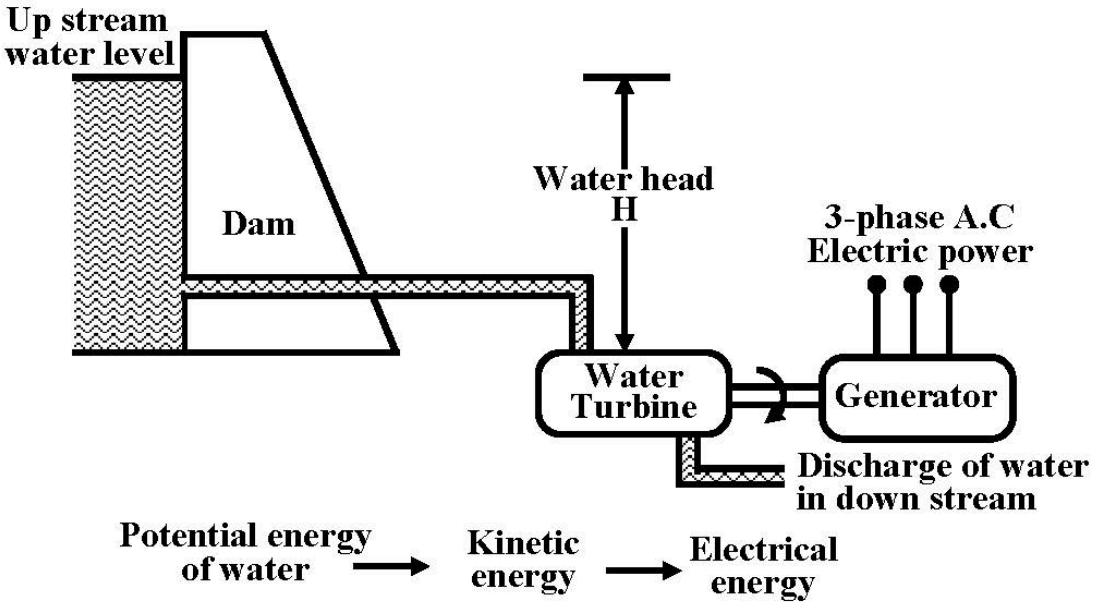
Thermal Power Plant



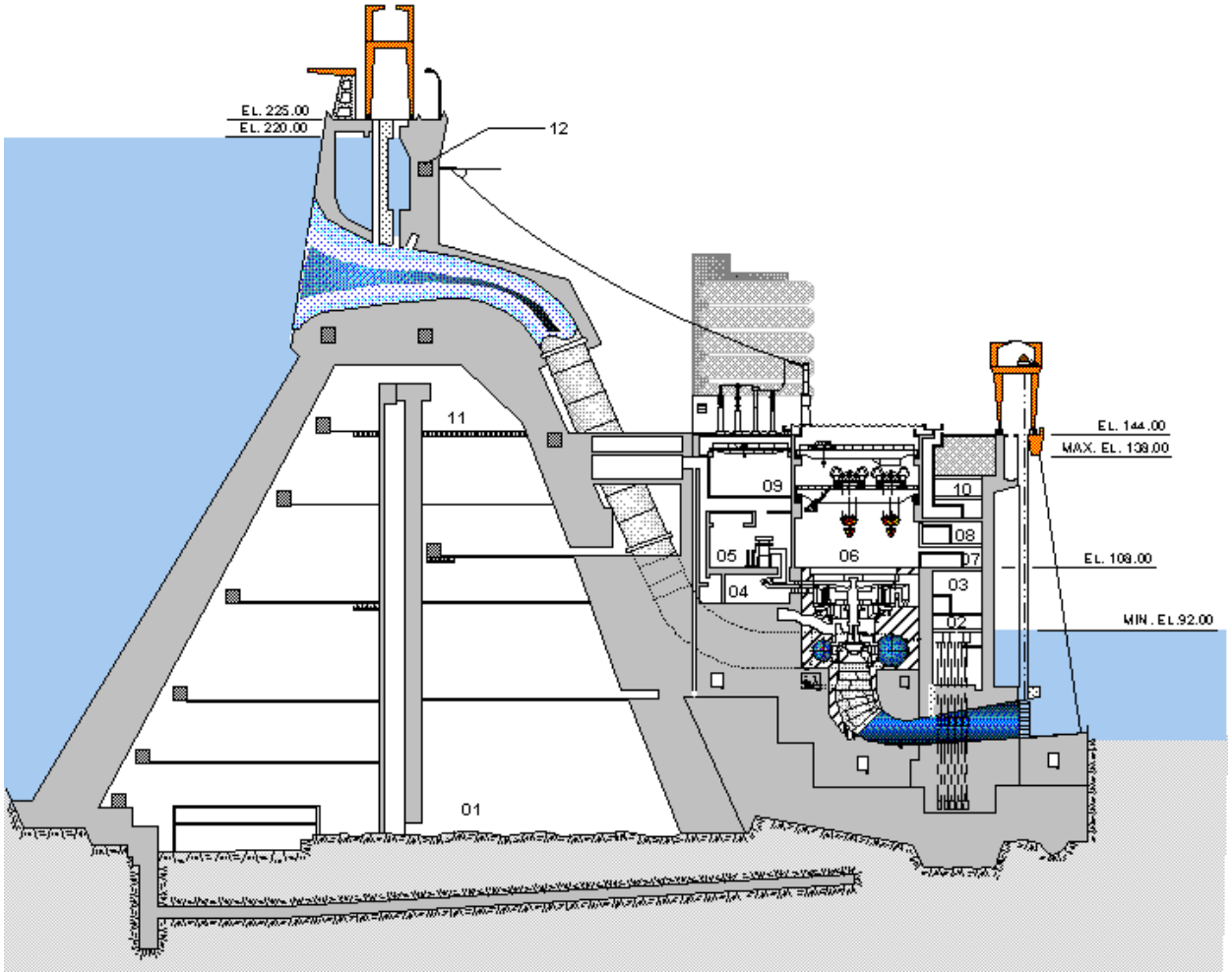
Thermal Power Plant

Power Plants (Contd.)

- Hydel
  - ✓ Eco-friendly
  - ✘ High initial cost



Hydroelectric Power Plant



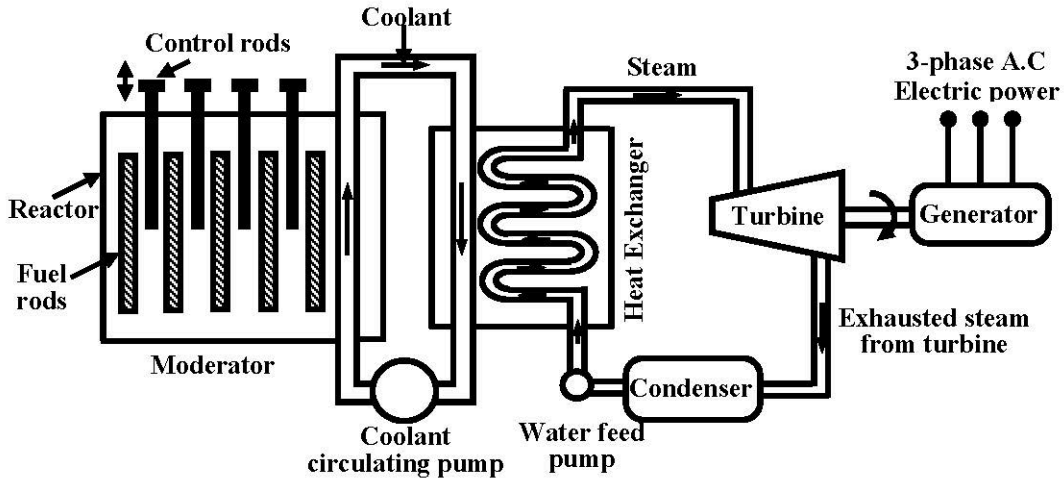
Hydroelectric Power Plant

Hoover

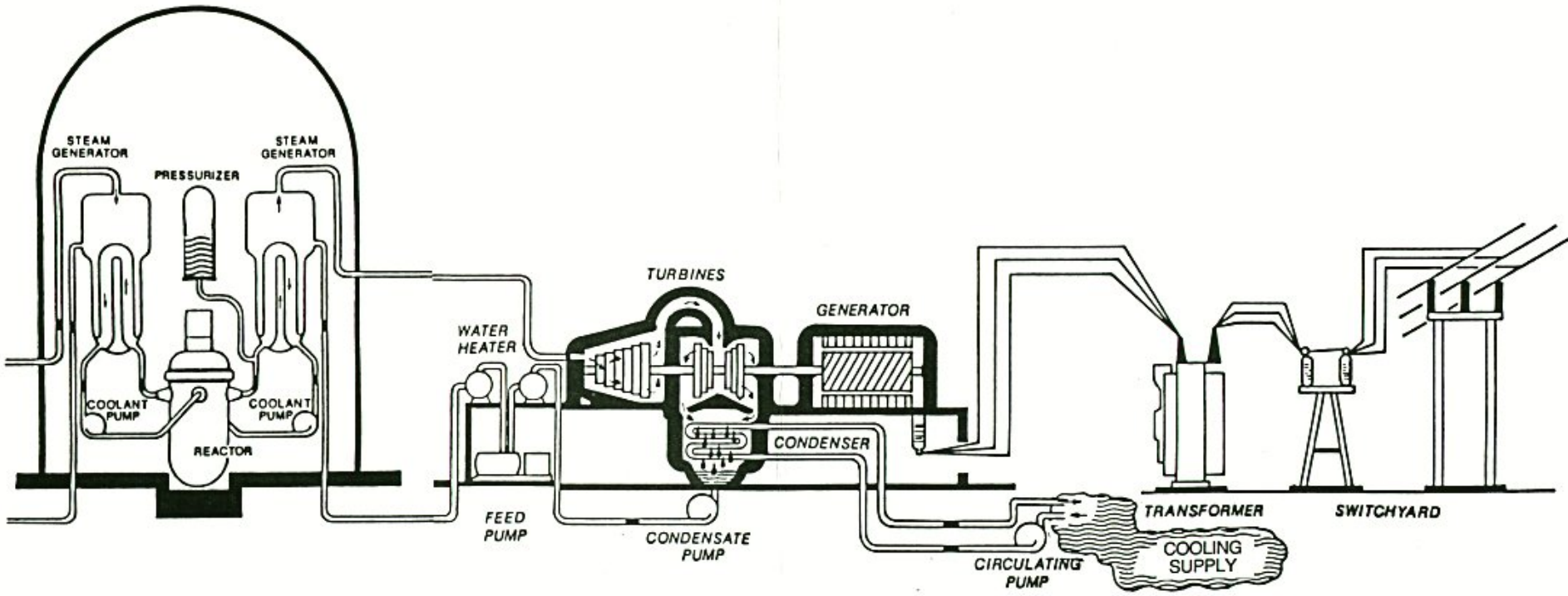
Tehri

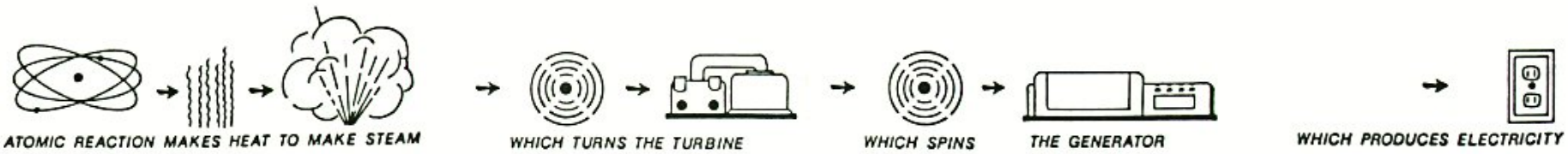
Power Plants (Contd.)

- Nuclear
  - Bulk power generation by nuclear fission of ^{235}U
  - When ^{235}U is bombarded by neutrons, a lot of heat energy along with additional neutrons are produced which further bombard ^{235}U producing more heat and more neutrons. Thus a chain reaction sets up.



Nuclear Power Plant





Nuclear Power Plant

Power Plant Components

- ELECTRICAL
  - Generators & Turbines
  - Transformers
  - Switches
  - Busses
  - Circuit Breakers
  - Capacitor Banks
- MECHANICAL
  - Conveyors
  - Silos
  - Boilers
  - Scrubbers & Stacks
  - Pumps
  - Cooling Towers

Total Generation

Method of generation	in MW	% contribution
Thermal	77 340	69.4
Hydel	29 800	26.74
Nuclear	2 720	3.85
Total generation	1 11 440	-

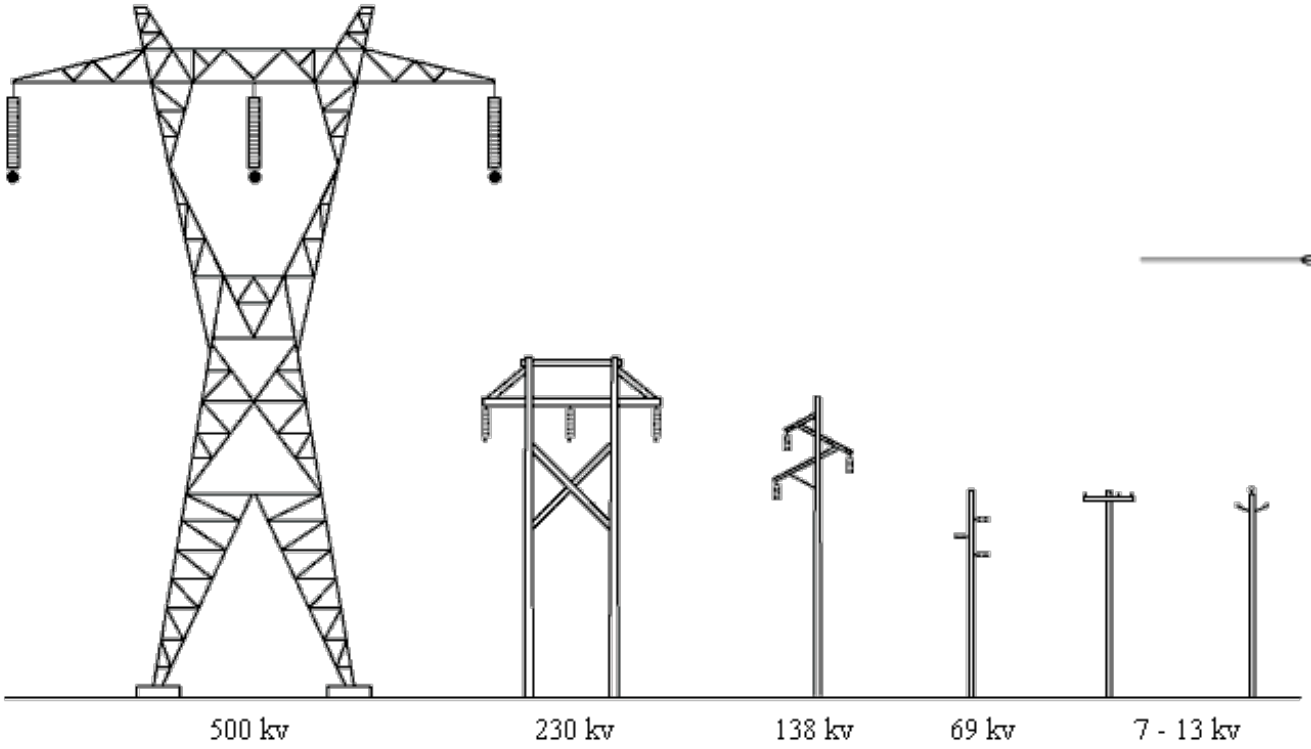
Non-Conventional Sources

- Wind
- Solar
- Fuel Cell
- Tidal Waves

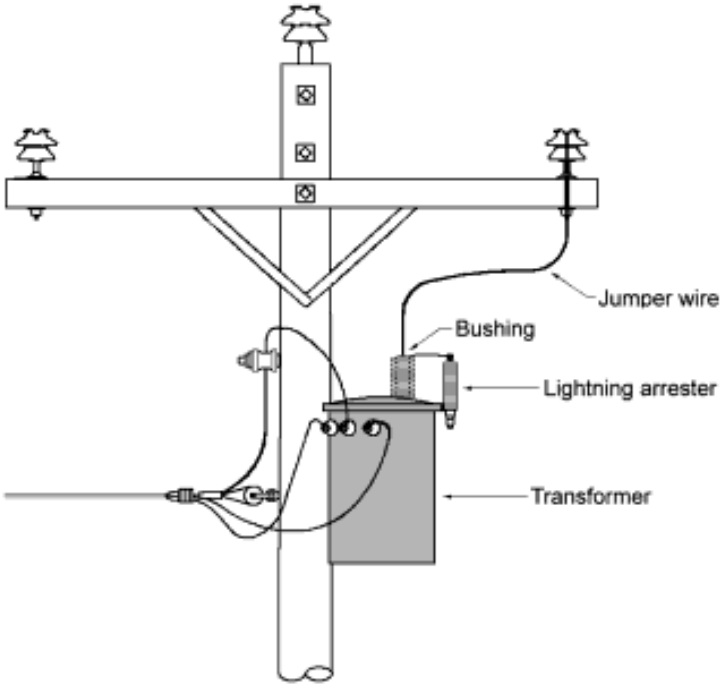
Transmission of Power

- From power station to consumers
- Example:
  - 120 MW at 10 kV => Current of 8660 A
  - 120 MW at 400 kV => Current at 261.5 A
- Smaller current =>thinner transmission line (less cost)
- Typical transmission voltage: 132 or 220 or 400 or 765 kV
- Step up and down transformers

Transmission Structures



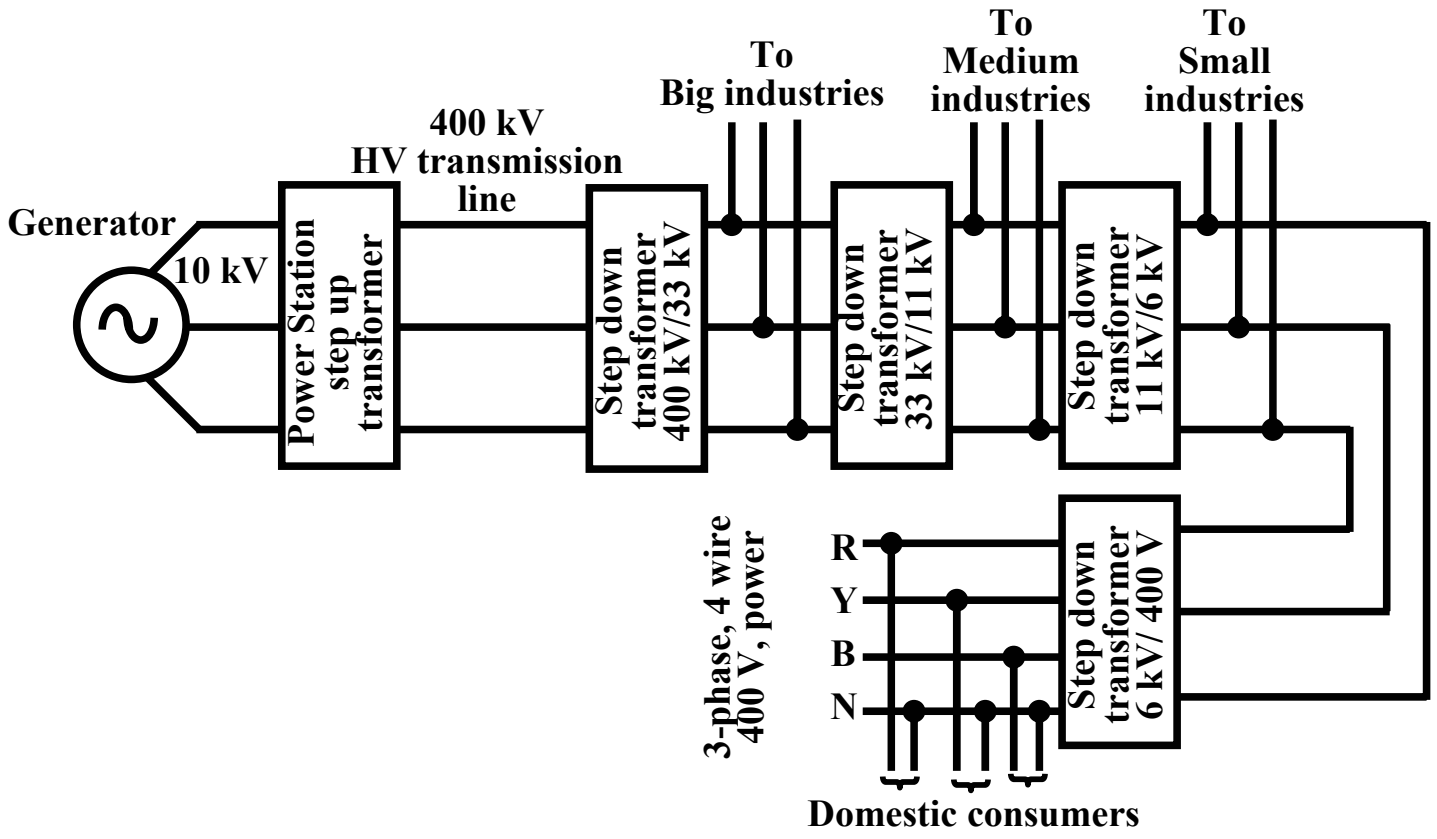
long-distance



neighborhood

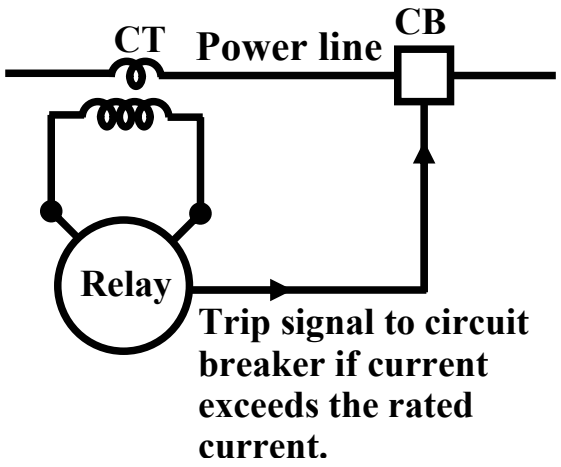
Substations

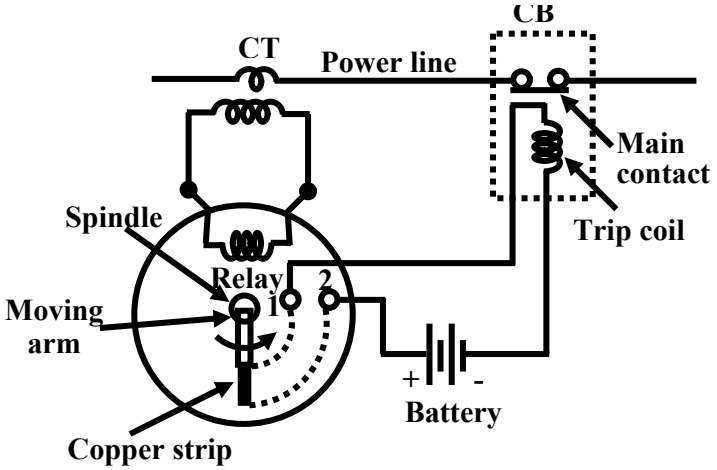
- Include transformers, circuit breakers, meters, relays



Substation (Contd.)

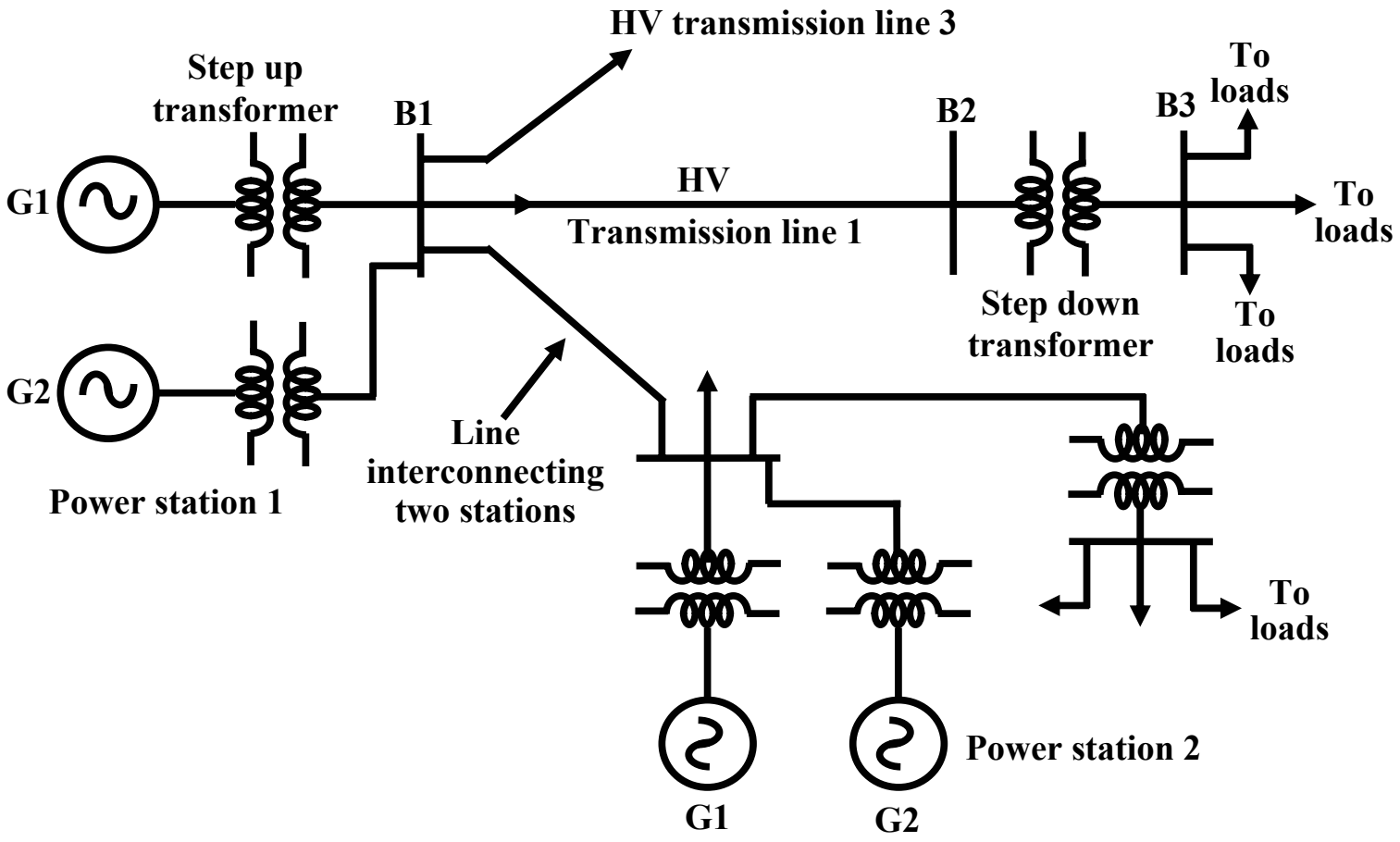
- Circuit Breakers
  - Isolate the transformer from incoming and outgoing lines
  - Automatic operation using current transformer and overcurrent relay





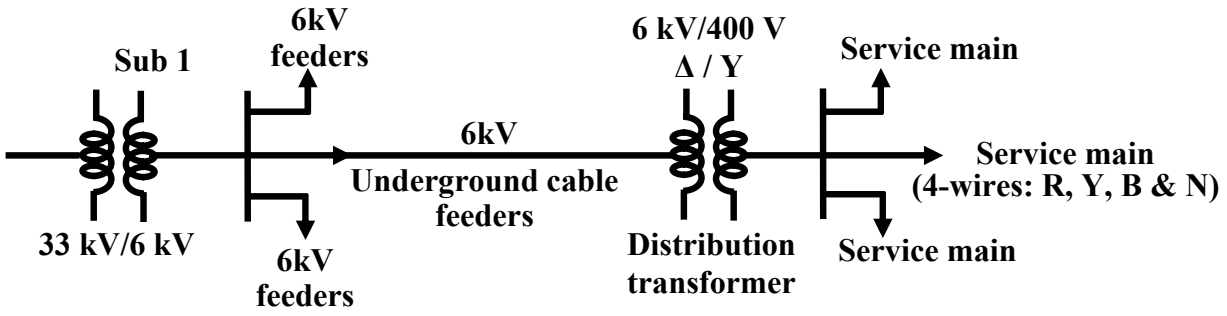
  - Potential Transformer to connect measuring instruments

Power System



Distribution System

- Consumers
  - LT (Low Tension): single phase, 220 V, 50 Hz
  - HT (High Tension): 33 kV or 22 kV



- Overhead or underground lines
- ~40% of power system investment is in the distribution system equipment

Distribution System

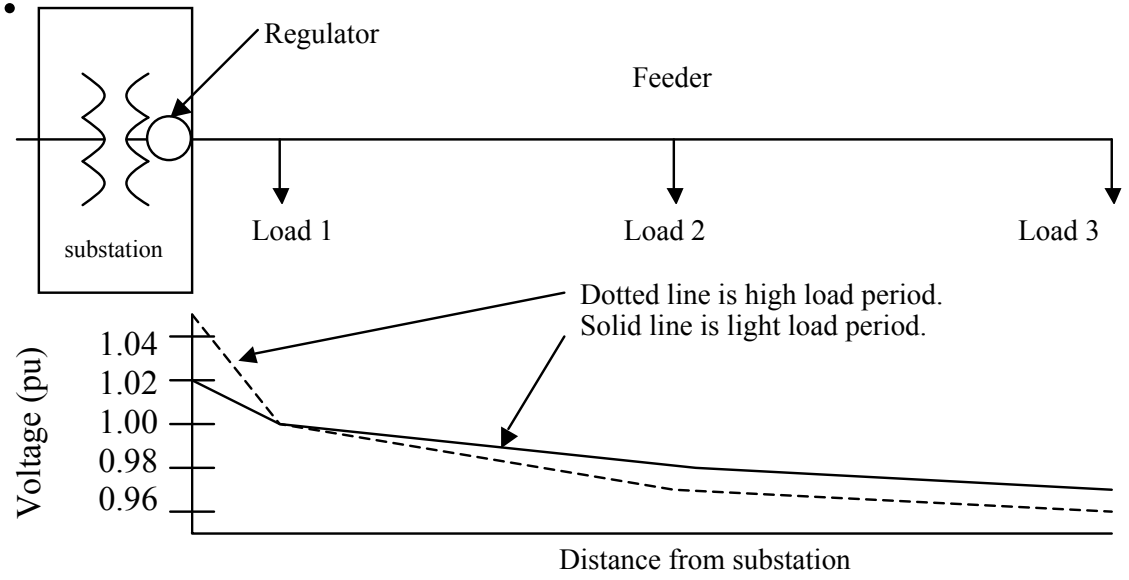
- 3 subsystems
  - Distribution substation
  - Primary distribution system
  - Secondary distribution syste

Distribution Substation

- Four functions
  - Voltage transformation
  - Switching and Protection: switches disconnect portions of the network and circuit breakers interrupt short-circuit current
  - Voltage regulation: to regulate the voltage along the feeder as the load varies
  - Metering: Current measurements

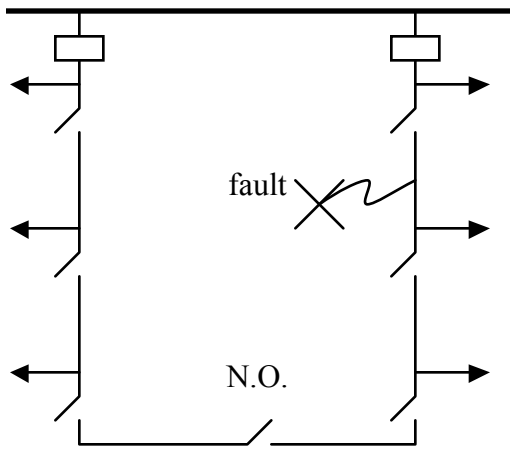
Voltage Regulation

- Ways to do this include substation load tap-changing transformers (LTCs), substation feeder or bus voltage regulators (employed in Fig. 3), line voltage regulators, and fixed or switched shunt capacitors.



Primary Distribution System

- 3-phase feeders from the substation to 1 or more secondary distribution systems
- Radial (most often) or looped (for reliability in dense urban areas)
  - ✘ Looping: Complex protection and voltage control
  - ❑ Can use normally open switch in loop



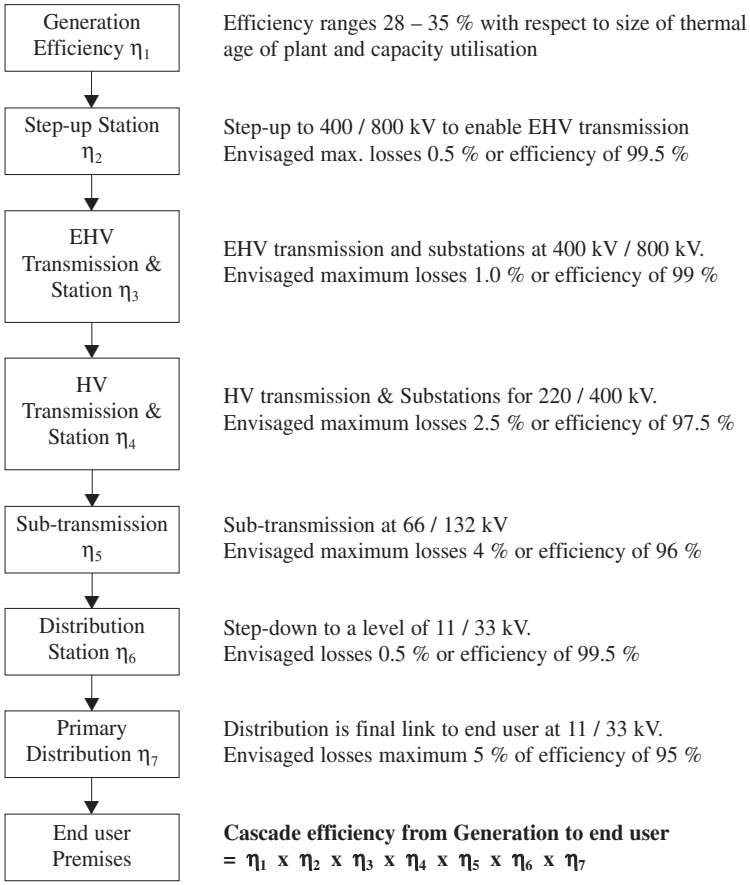
Secondary Distribution System

- Branching from the main feeder are laterals, also known as taps or branches. The laterals may be three-phase, two-phase (two phases of the three-phase feeder with a neutral), or single-phase (one phase from the single phase feeder and a neutral). The laterals are usually protected with fuses so that faulted laterals do not cause interruption at the feeder level.

Cascade Energy Efficiency

- The efficiency of electricity flow from generation to the end user

The cascade efficiency in the T&D system from output of the power plant to the end user is 50% (i.e. 0.83 x 0.95 x 0.9 x 0.70 = 0.5)

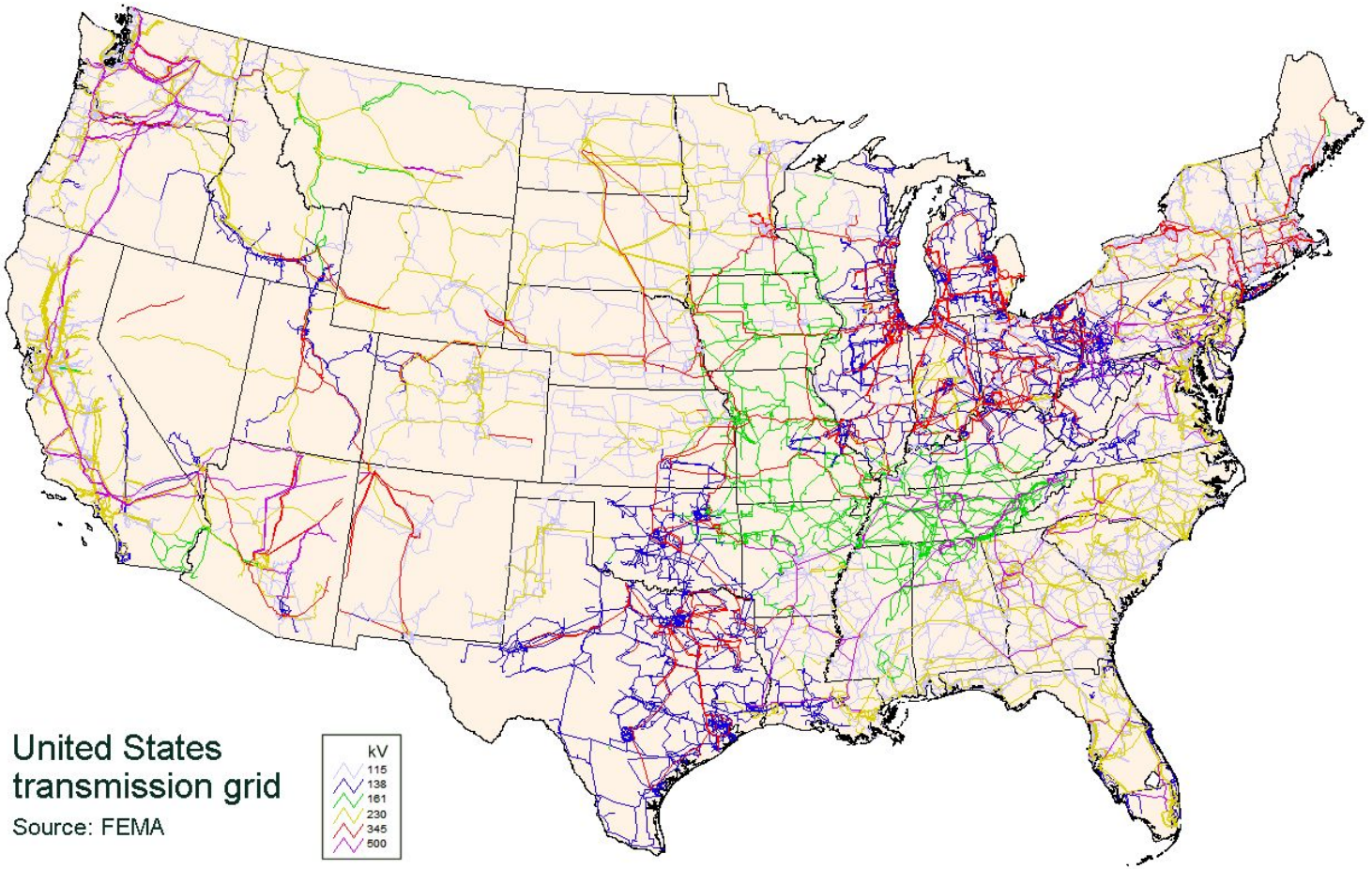


Electrical Grid

- Interconnected network for delivering electricity from suppliers to consumers
- Power Grid Corporation of India
  - planning, coordination, supervision and control over inter-State transmission system and operation of National & Regional Power Grids.

Power Grid of India

National Power Grid in USA



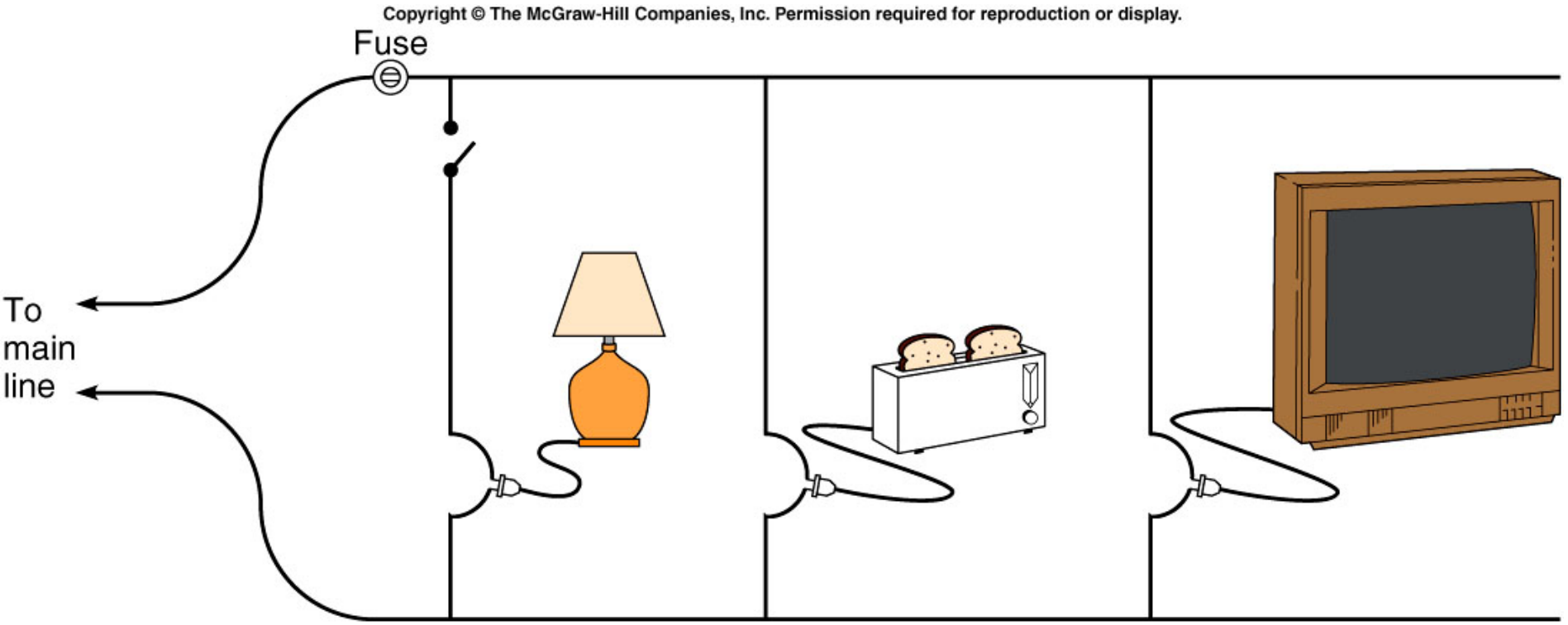
Appliances

- Exercise: Name some!

AC Adapter

- Purpose?
  - Input?
  - Output?

Household Circuits



Power and Current Ratings of some Common Appliances

Appliance	Power (W)	Current (A)
Stove	6000 (220V)	27
Clothes dryer	5400 (220V)	25
Water heater	4500 (220V)	20
Clothes washer	1200	10
Dishwasher	1200	10
Iron	1100	9
Coffeemaker	1000	8
TV	100	0.8

Bimetallic Thermostat