ELEC 342
Electromechanical Energy Conversion and Transmission

2025-26 Winter Term 2

Lecture 1

January 6, 2026

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Course logistics

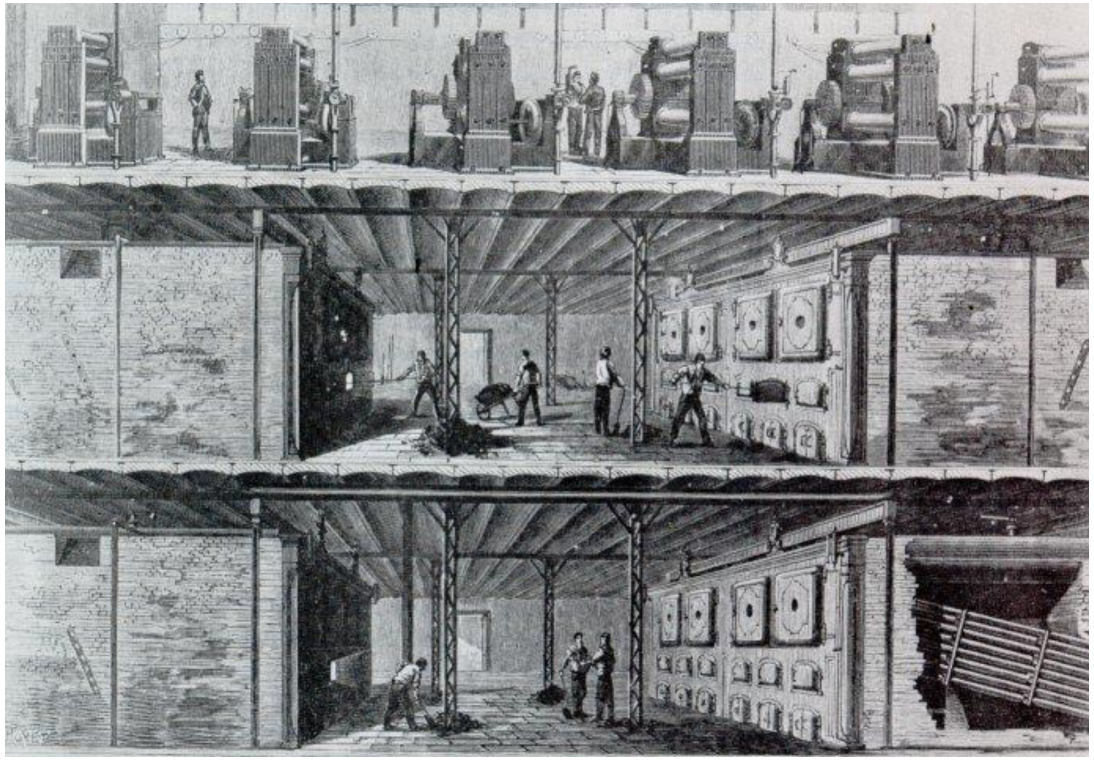
- Syllabus available on Canvas

- About me:
  - Joined UBC in January 2025
  - Working on the application of power electronics in power systems
  - Let me know if you are interested in joining my group

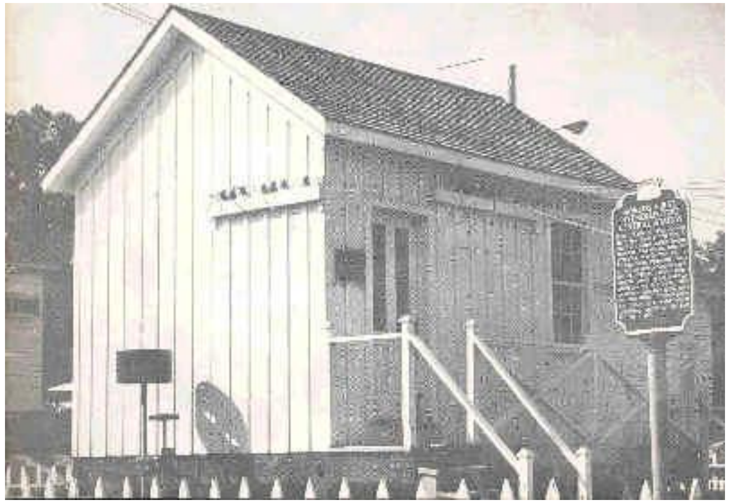
History & motivation

Early 1880s

1882: Thomas Edison's coal-fired Pearl Street Plant provides a central supply of DC power to Manhattan.

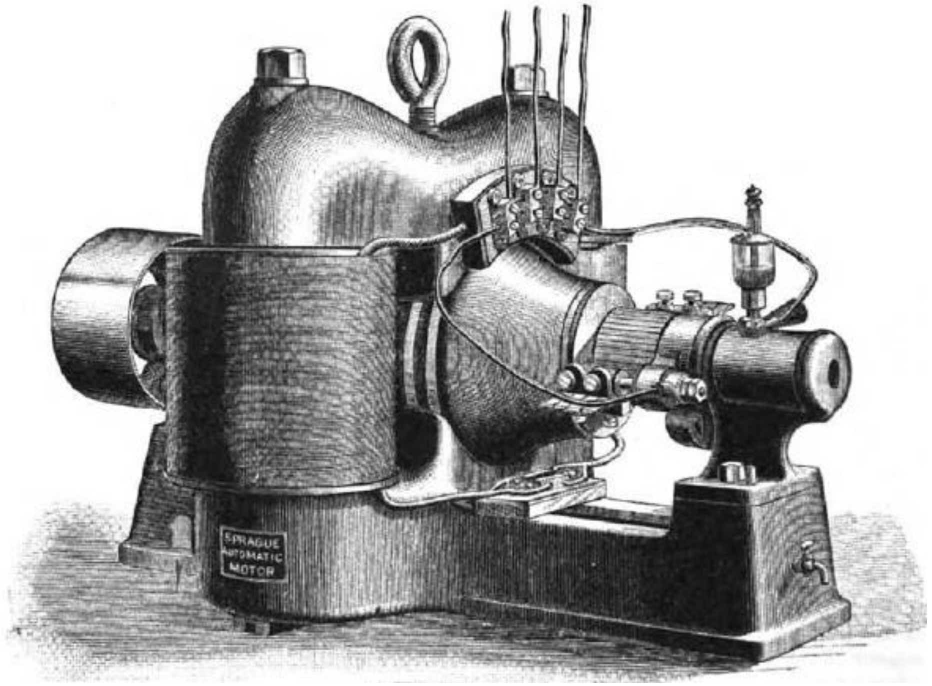


1882: Thomas Edison's hydro-electric Vulcan Street Plant supplies DC power to paper companies in Appleton, WI.

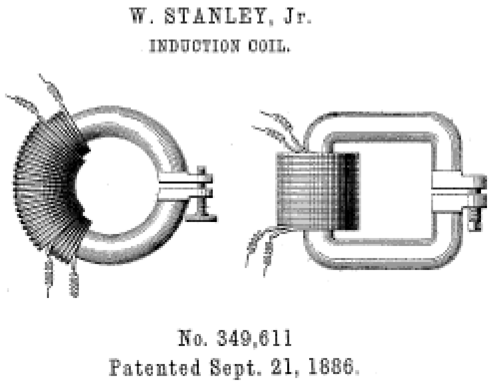


Mid-1880s

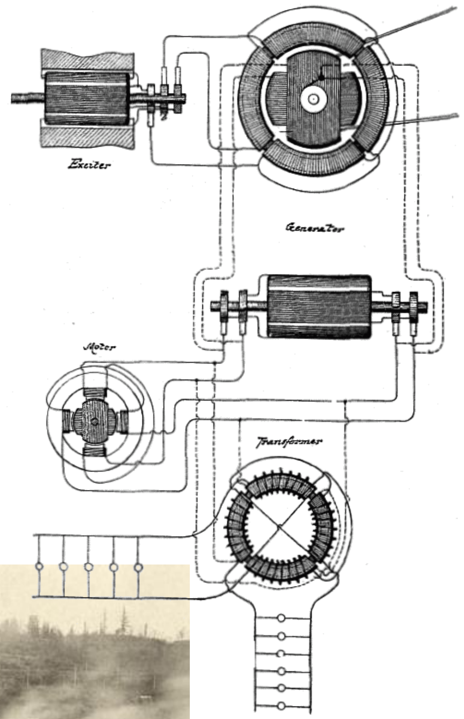
1884: Frank Sprague
produces DC motors.
“Father of Electric Traction”.



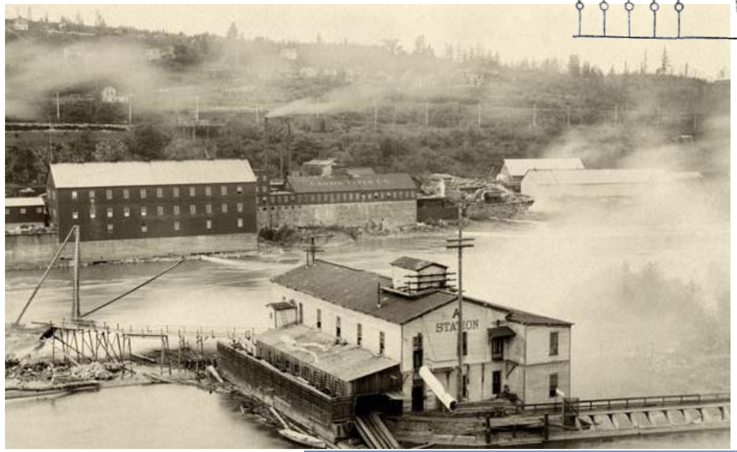
1885: William Stanley
develops commercially
practical transformer.



Late 1880s and 1890s



1888: Nikola Tesla patents AC induction and synchronous motors as well as poly-phase distribution systems.

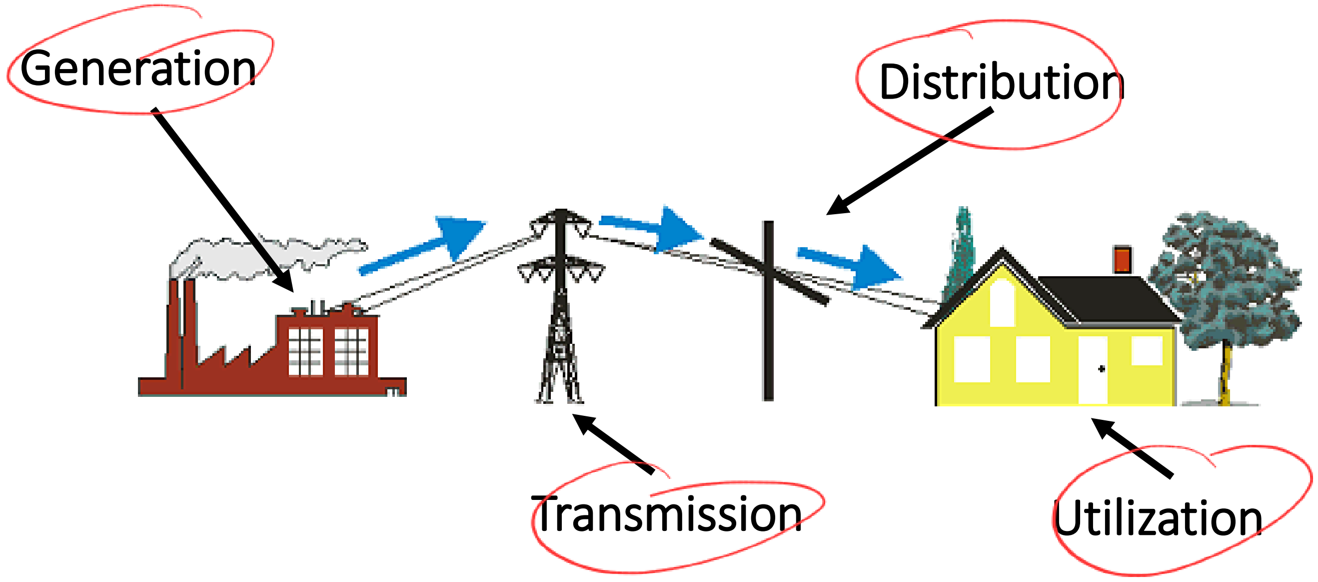


1889: Single-phase AC transmission in Oregon.

1896: Three-phase AC transmission from Niagara Falls to Buffalo, NY.

How power system works

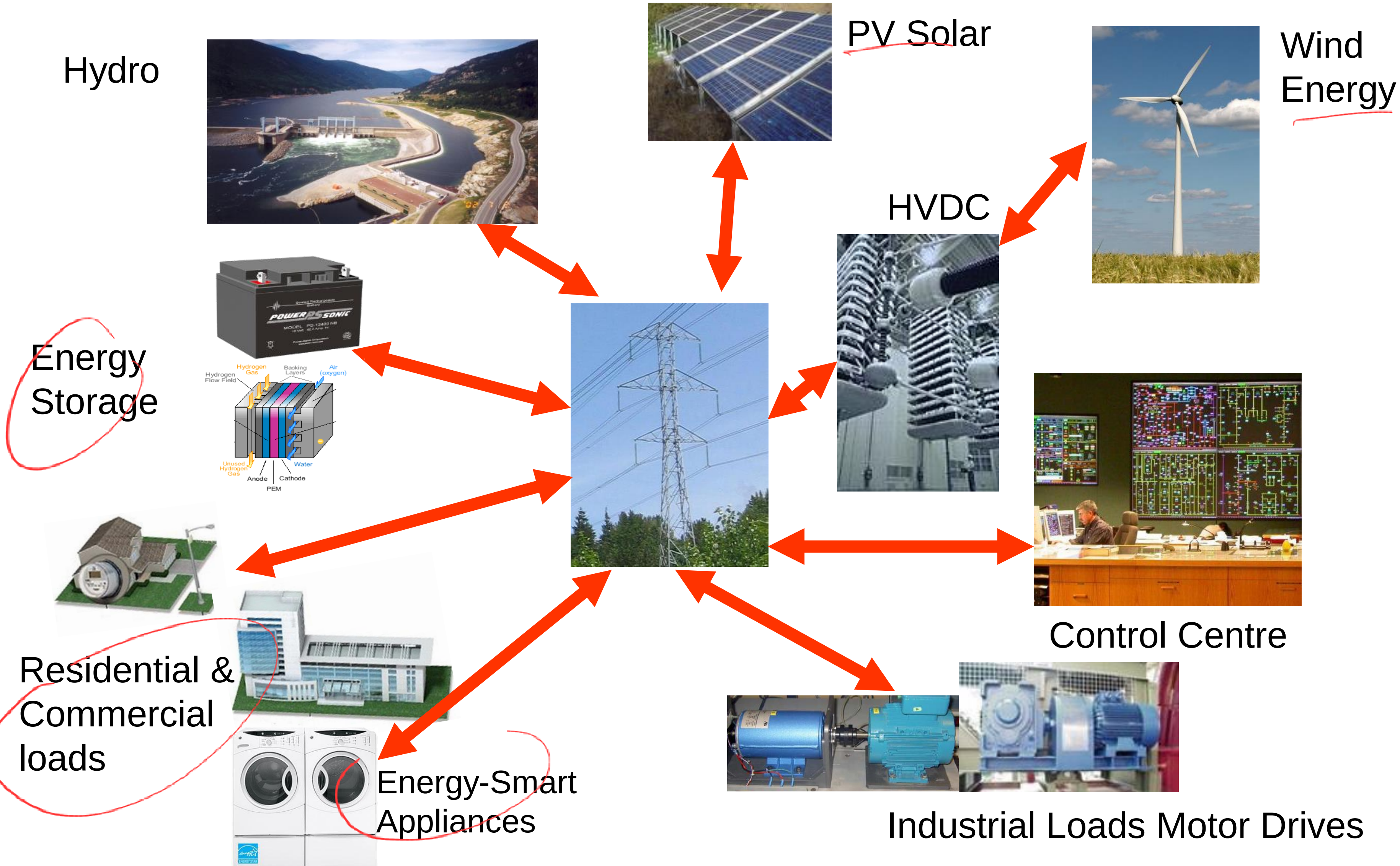
- The electricity infrastructure has been the engine that has driven the world economy for over 100 years, and represents the most complex system built by humankind



Complexity of our power grid

Generation, Transmission, Distribution, Utilization

Modern Electric Grid – A very complex system

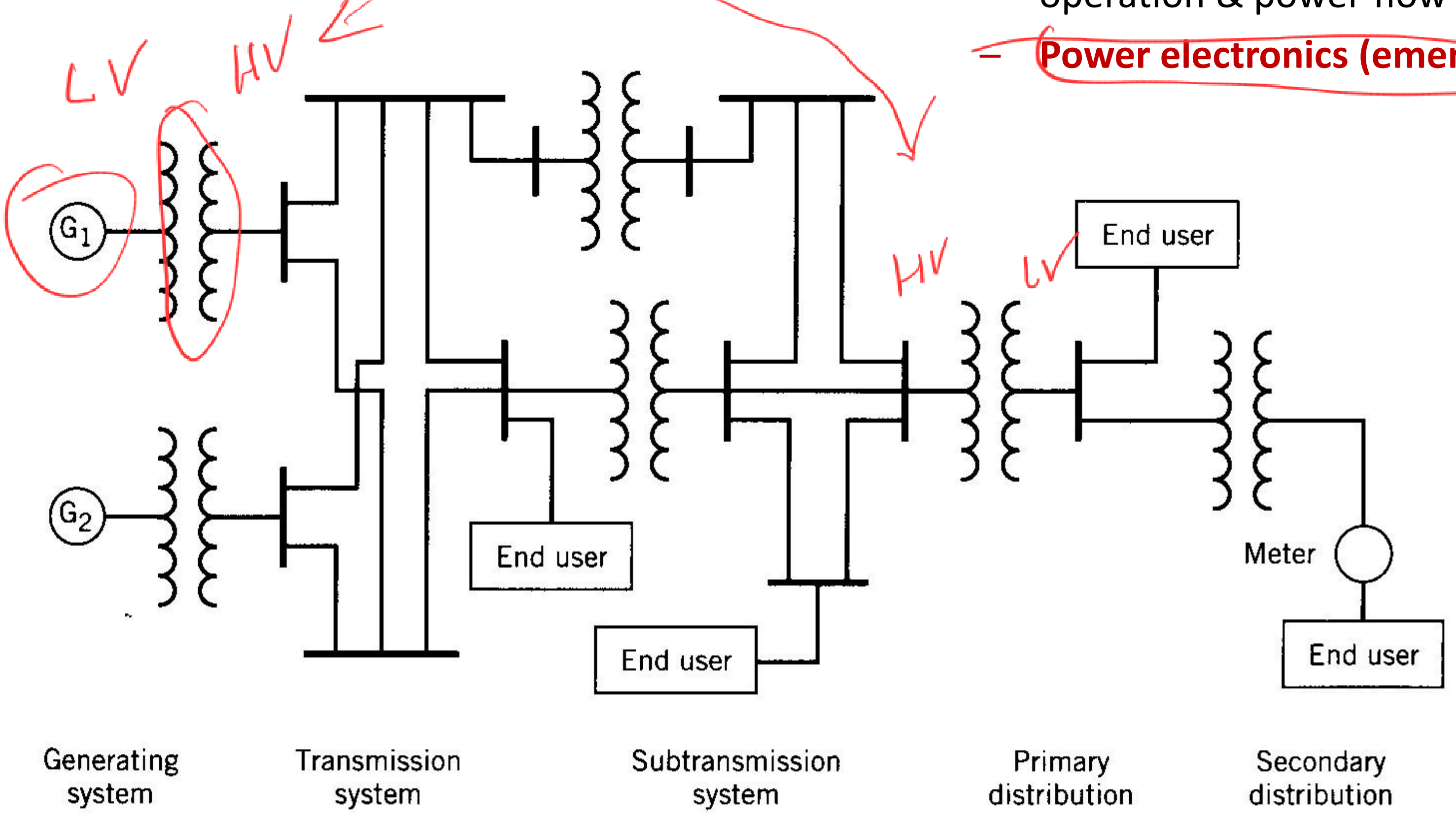


- **Transmission & Distribution**
  - Transmission ~ 138 to 765 kV
  - Sub-transmission ~ 34 to 138 kV
  - Distribution ~ 4 to 34 kV
  - Service / Customer level ~ 240, 208, 120

- **Components**
  - – Wires, cables – transmission of power
  - – Tower – support structures
  - – Transformers – converting voltage levels
  - – Circuit breakers, relays – protective devices
  - – Control Centers – ensure reliable operation & power flow
  - – **Power electronics (emerging)** ⟸ electrification

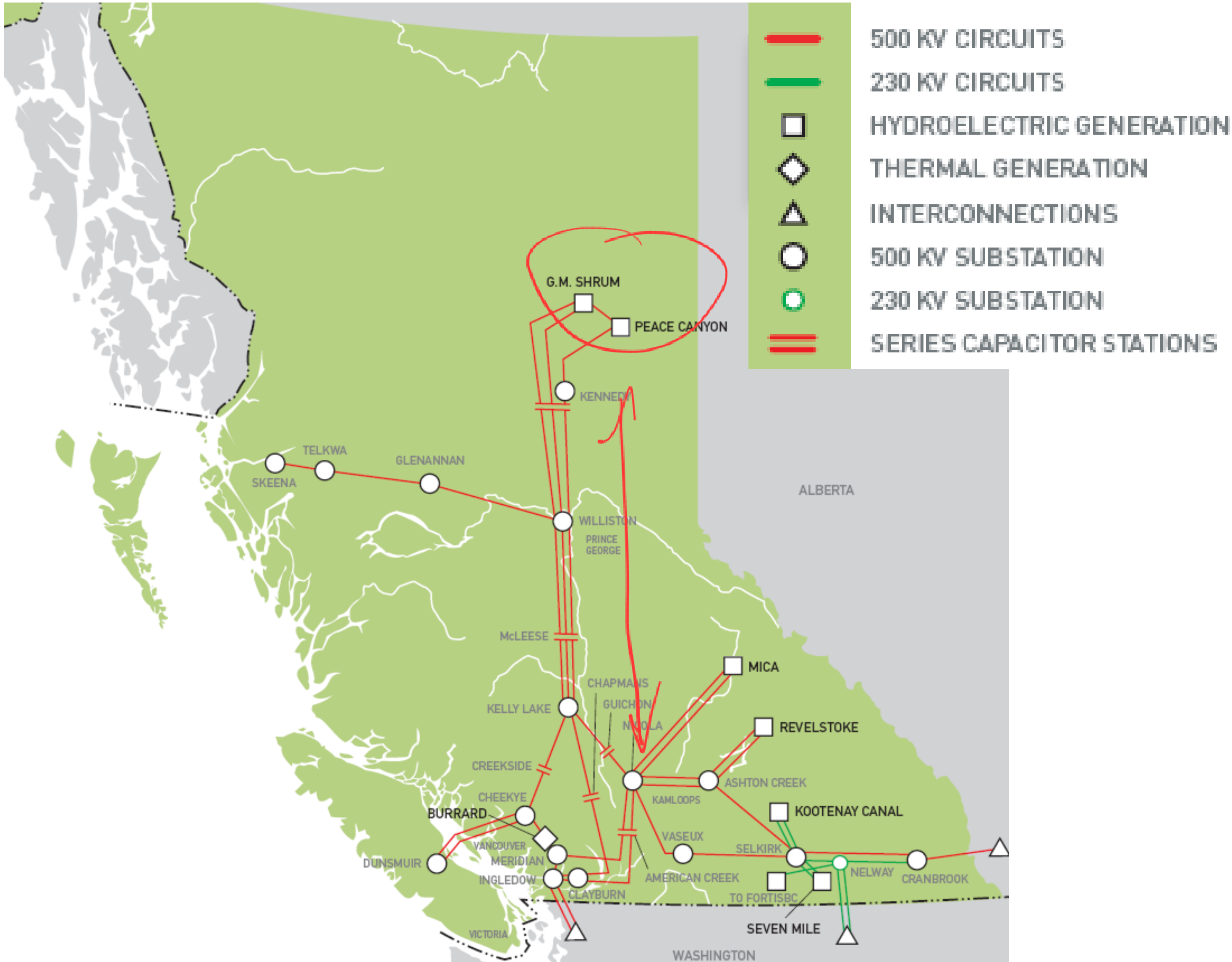
Losses ∝ Current

Conservation of power



BC Transmission System

- Almost all electricity in BC (10 ~12GW) is produced by Synchronous Generators



Electromechanical Energy Conversion

- Generation of Electricity – Big Scale

Thermal Power Plant

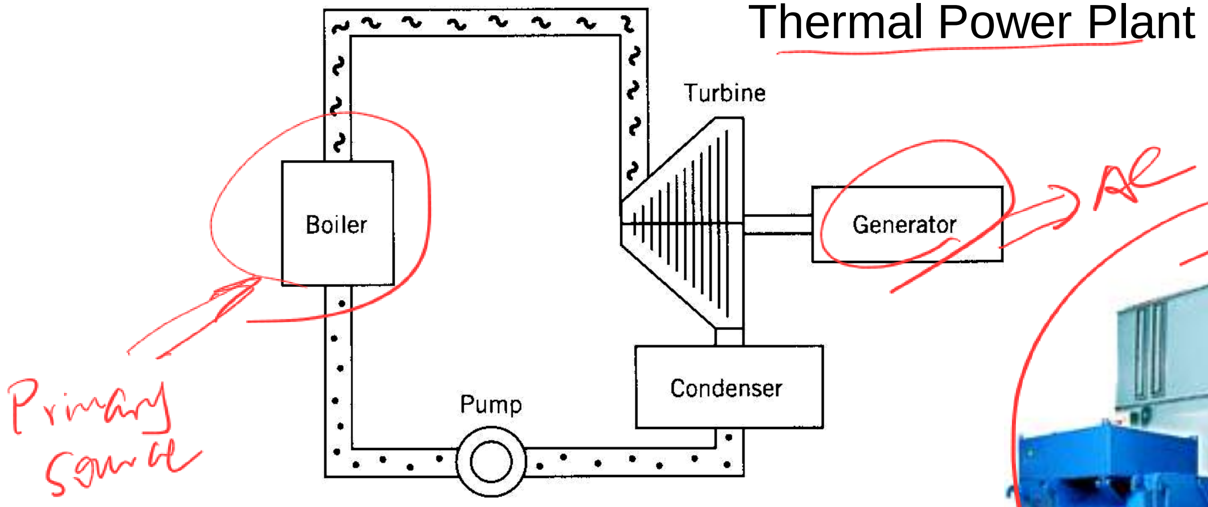
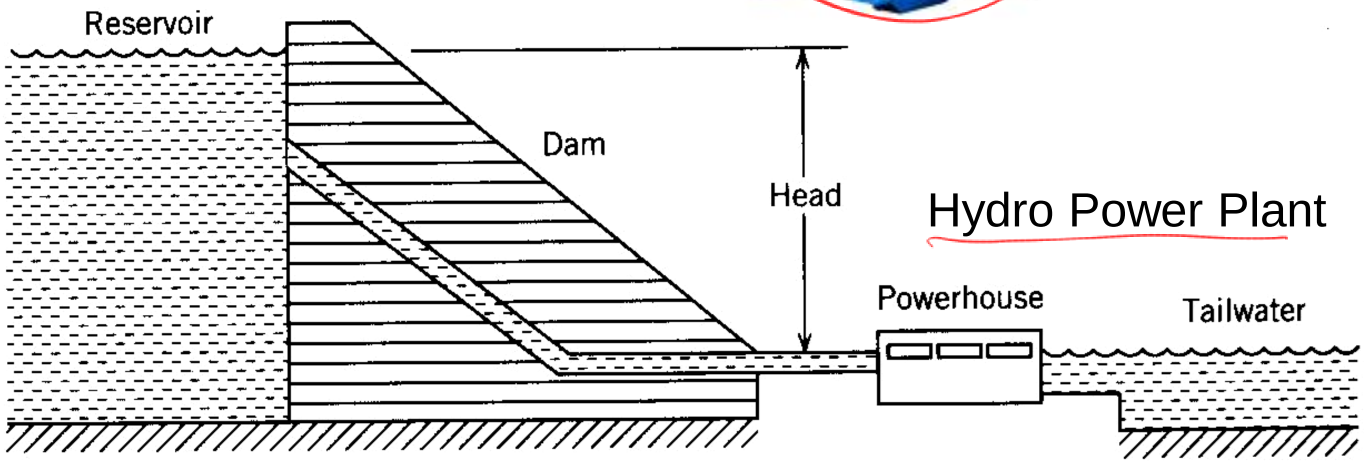


figure. King Mountain Wind Range, consisting of 214 1.3-MW wind turbines in Upton County, West Texas. (Courtesy: Bonus Energy Systems A/S.)

Wind Power



Hydro Power Plant

Electromechanical Energy Conversion

Electrical Energy Generation

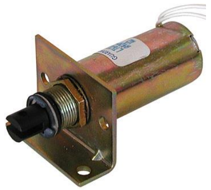
- Almost all electricity produced in BC (10 ~12GW) is produced by Synchronous Generators

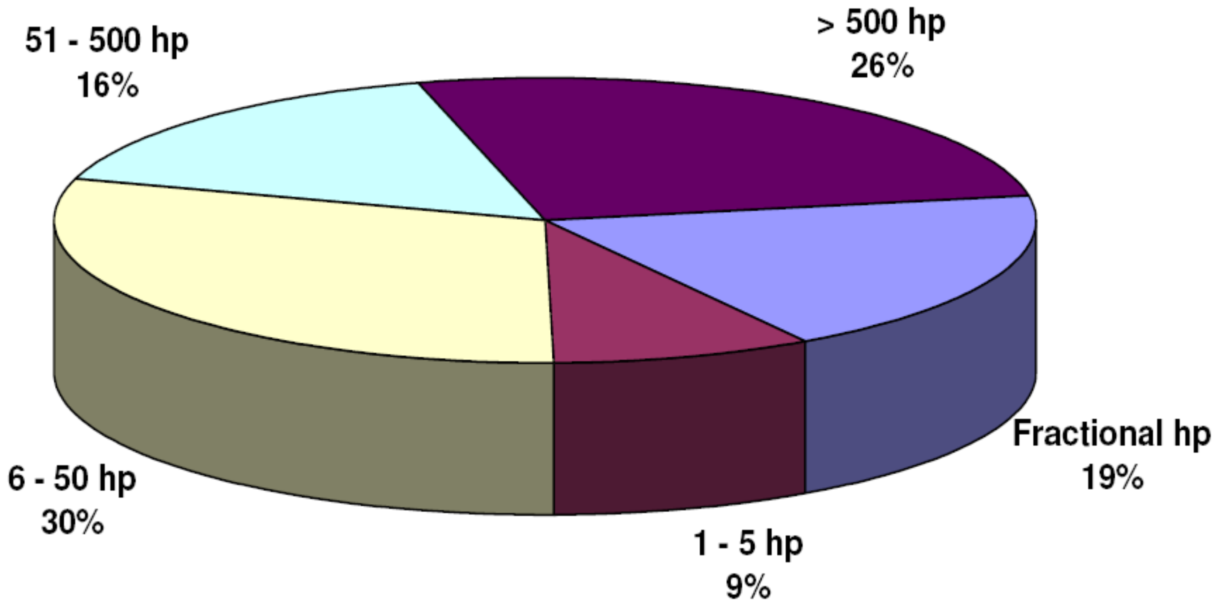
Electrical Energy Utilization

- About 65% of all electricity is consumed by motors: induction, synchronous, etc.
- For industry it is about 85%

Electromechanical Energy Conversion Devices

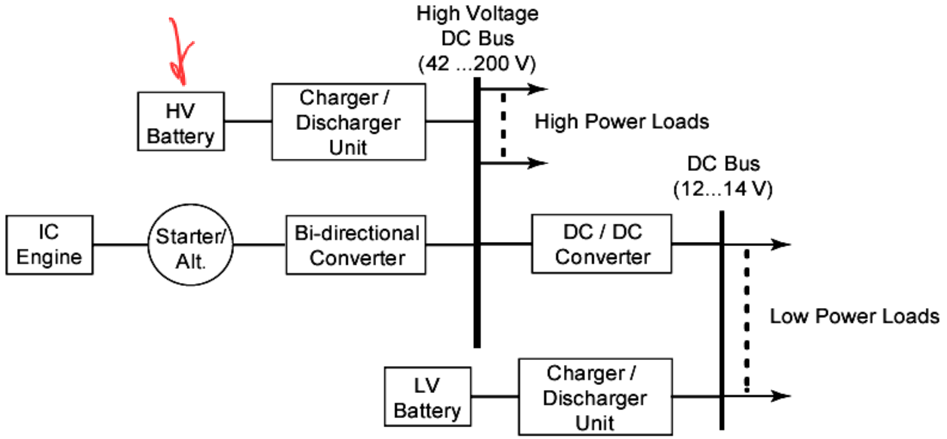
- Predominant way of generating and consuming electrical energy





Applications of Electromechanics

Modern Transportation → More Electric Vehicle



Diesel-Electric

Liebherr T282B earth-hauling truck 2.7MW AC Propulsion

Hybrid

Toyota Hybrid, operates at 288V, reaches 30kW

All-Electric → Zero Emission Transportation

Canada Line (Richmond-Airport-Vancouver Line) SNC-Lavalin & Rotem Company

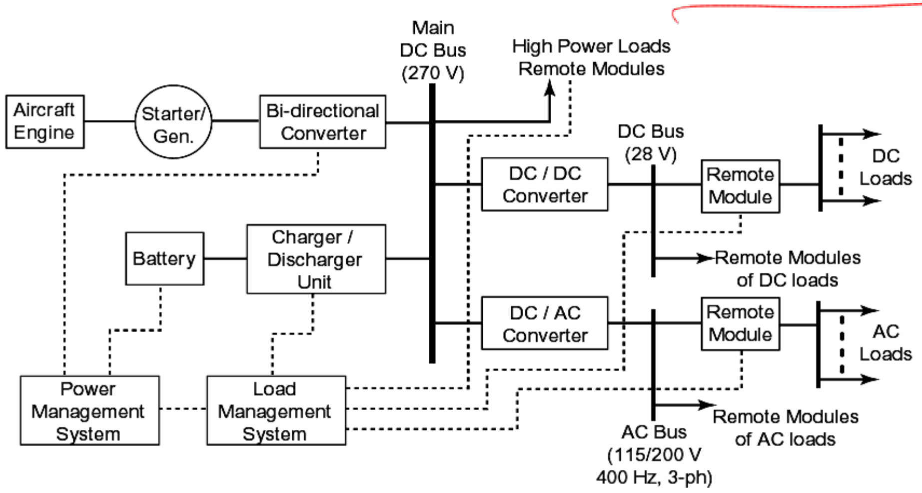
Vancouver TransLink Trolley Bus New Flyer Industries

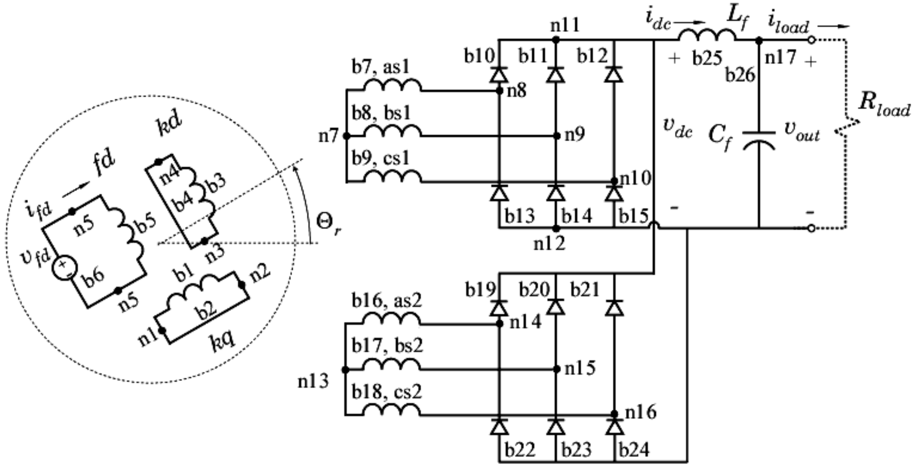
All-Electric

Tesla Roadster, Induction Motor, reaches 200 kW

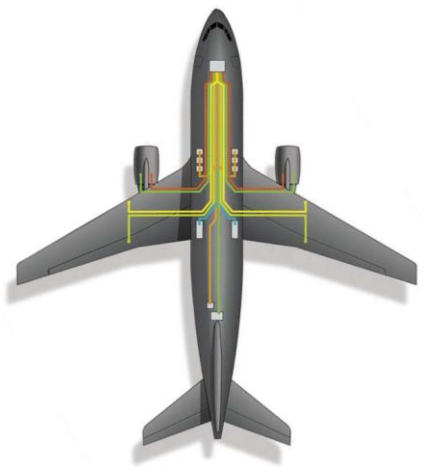
Applications of Electromechanics

Modern Aircraft → More Electric Aircraft





High-Speed, Low-Weight, High-Phase-Count Motors, Generators and Converters



Airbus A380

Antares 20E
42kW BLDC Propulsion

Electric Toys
BLDC Propulsion

Drones
BLDC Propulsion

Electromechanics Applications

Electromechanics Devices

Manufacturing

Automotive

Aircraft

Ships

Computers

Office

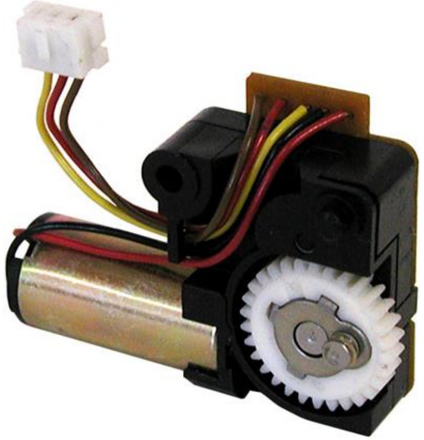
Household

…

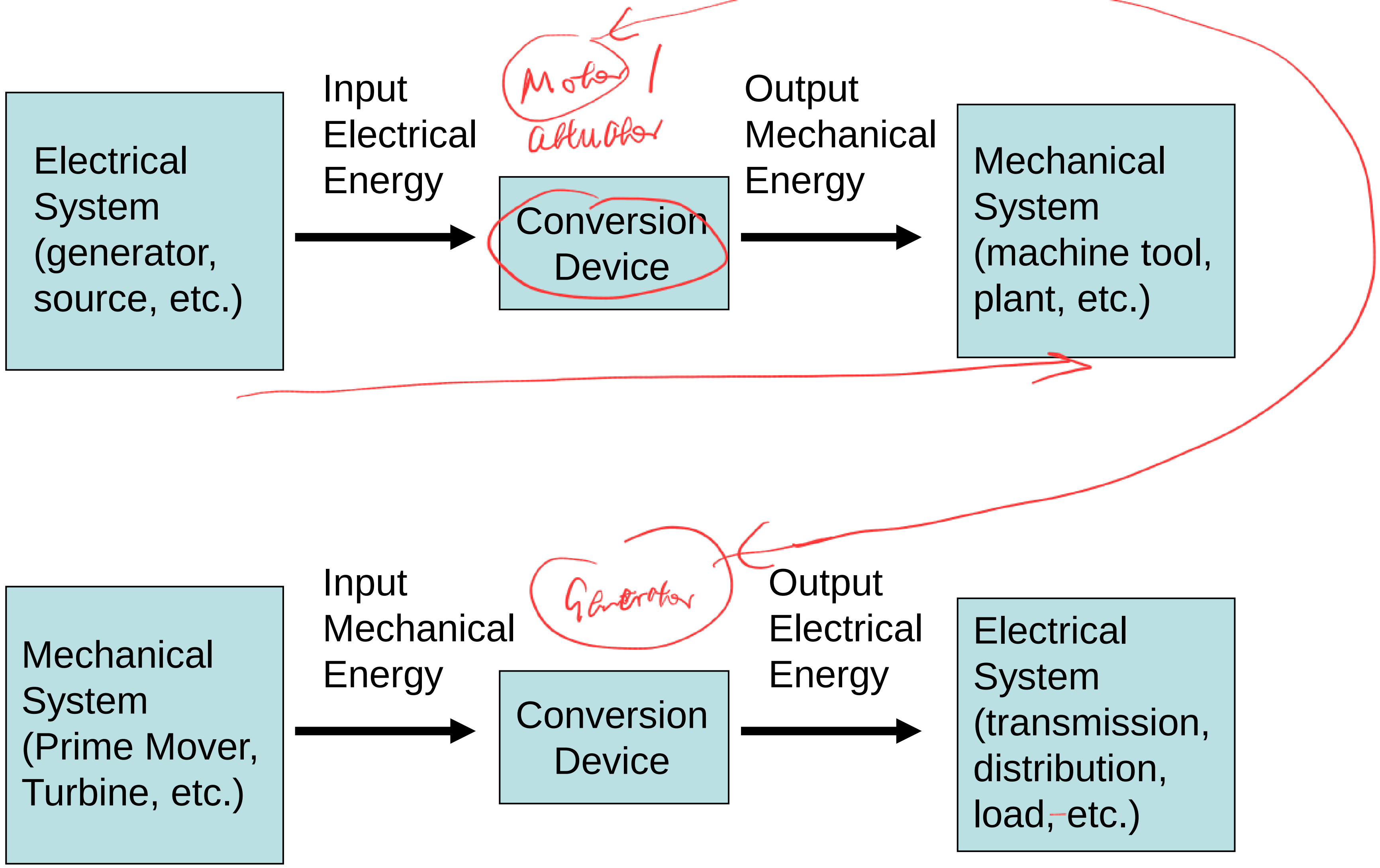






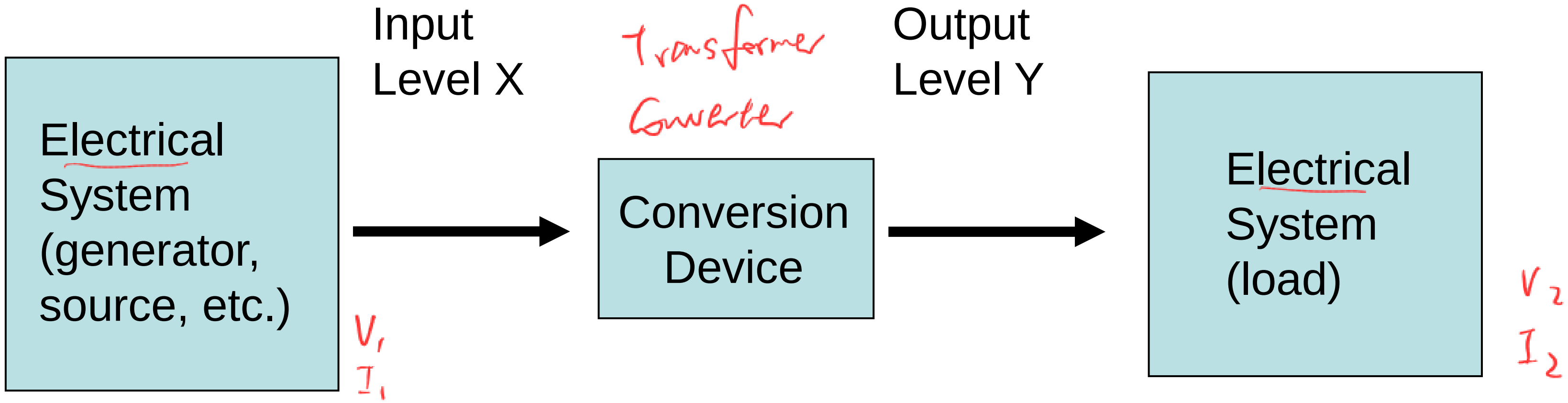
Electromechanical Energy Conversion



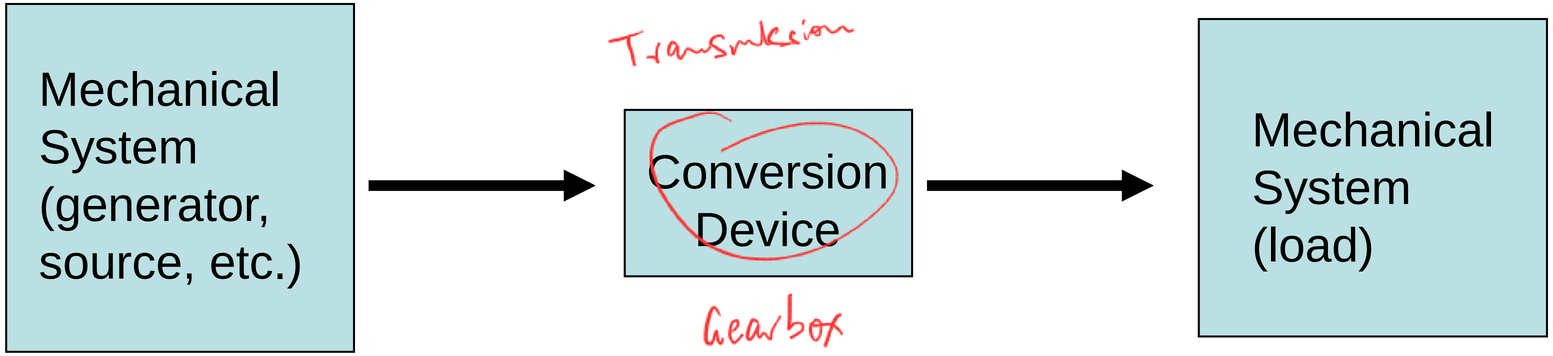
Is the energy conversion process reversible?

Electromechanical Energy Conversion

- Transformation of Electrical Energy



- Transformation of Mechanical Energy



Electromechanical Energy Conversion

- Electrical Machines
  - Stationary
    - Transformers
  - Rotating
    - Motors, generators

  We will try to cover these topics

  - Linear Devices
    - Solenoids, linear motors, other actuators

  - Power electronics

  - Devices may operate with DC or AC

- Power Electronics (Switched Mode Power Supplies (SMPSs), Motor & Actuator Drivers, …)
  - Rectifiers
    - AC to DC
  - Converters
    - DC to DC
  - Inverters
    - DC to AC

- Very broad & interesting areas, require several courses to cover!
- **AC Circuits and Systems are required as background**

- Electrical machine
- Power system

- Power supplies (DC-DC)

- Grid-level power electronic (AC-DC)

Lots of job opportunities in power engineering

- Utilities: BC Hydro, Hydro One, IESO, …
- Consulting: Arup, Hatch, Stantec, Powertech, …
- Manufacturing: Tesla, GE, Hitachi Energy, Siemens, Lucid, Rivian, …
- Big tech: Meta, Microsoft, Google, Oracle, Nvidia …
- Government

Lots of job opportunities in power engineering

Principal Power System Electrical Engineer
Microsoft · Mountain View, CA (Hybrid)

Responsibilities

- Define and design rack power systems to enable integration of a variety of IT gears into Microsoft data centers
- Work with cross-functional teams to drive product qualification full test coverage to meet product requirements and ensure product deployment
- Contribute to rack level power system solution roadmap with cross-functional teams and vendor partners to ensure long term scalability of Microsoft power infrastructure
- Lead system stability analysis using impedance-based methods and other advanced modeling techniques.
- Drive simulation and modeling efforts for system transient and steady-state analysis
- Collaborate with cross-functional teams on power delivery for high-performance compute (HPC), AI workloads, and ODM platforms.
- Define and enforce power system design standards, safety protocols, and compliance with global regulatory requirements.
- Mentor junior engineers and contribute to technical leadership across the infrastructure organization.
- Engage with external partners, suppliers, and academic collaborators to advance power system innovation.

Lots of job opportunities in power engineering

Power Systems Engineer, Google Data Centers
Google · Reston, VA (On-site)

Responsibilities

- Create and maintain detailed models of electrical single lines and layouts that will help analyze things like AI/ML fluctuations.
- Help implement solutions that lead to fast, cost effective construction and data center delivery.
- Develop power system dynamic and transient models working alongside executive data center engineers.
- Investigate renewable power generation, storage technologies and find best ways to implement them in models and reality.

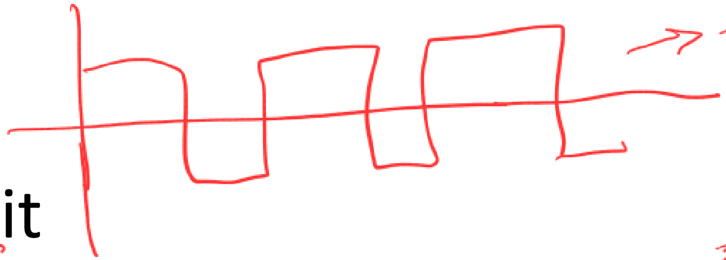
Module 1, Part 1: Review of AC Circuits & Phasors

Objectives & important concepts

- Concept of phasors & notations
- RMS value
- Phasor diagrams for basic RLC circuits
- Balanced 3-phase system, source, load, Y / D connection, line-to-line and phase voltages and currents, phase shifts
- Real, reactive, and apparent power in 1-phase and 3-phase systems, power factor

- Read Appendix B, get ready for Lab 1

AC circuits



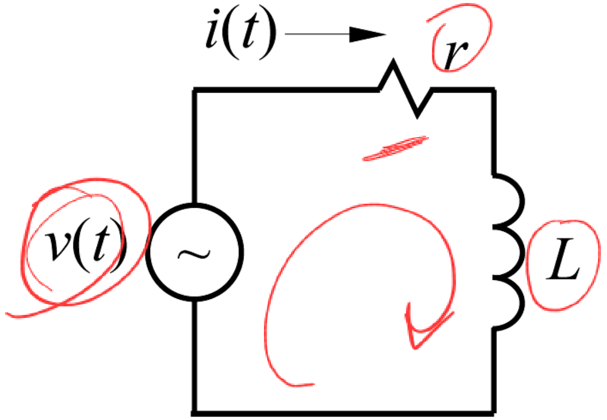
→ This waveform can not represent inductor current

→ magnetic field

- Consider linear inductive circuit

Inductor can store energy $E_L = \dfrac{Li^2}{2}$

- Where is this energy stored?
- Can the stored energy change instantaneously? → no, inductor current cannot change instantaneously

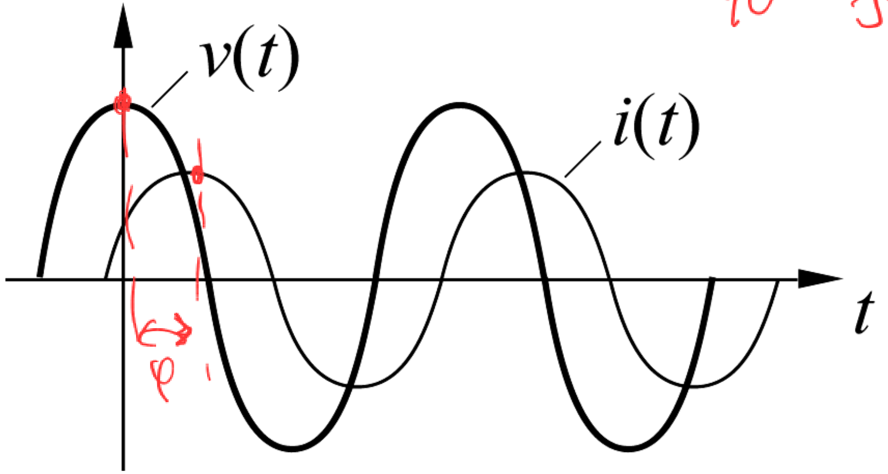


Steady-state Solution

$$v(t) = V_m \cos(\omega t)$$
$$i(t) = I_m \cos(\omega t + \varphi_i)$$

→ delayed by phase shift

→ 90° for L



Inductor: current lags voltage

KVL

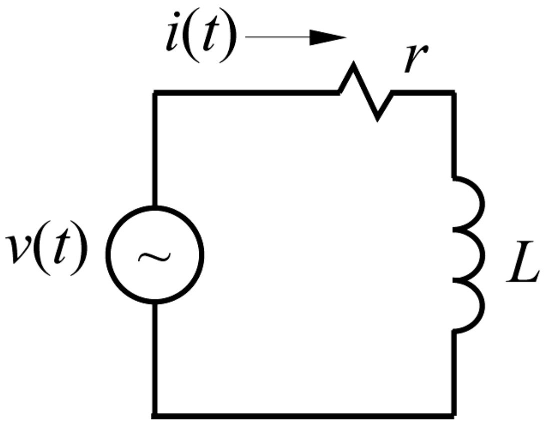
$$v(t) = ri + e = ri + \frac{d\lambda}{dt}$$
$$= ri + L\frac{di}{dt} \rightarrow \text{ODE}$$

Note: For steady state, we need to know only amplitude & phase

AC circuits

- Consider linear inductive circuit

Inductor can store energy $E_L = \dfrac{Li^2}{2}$

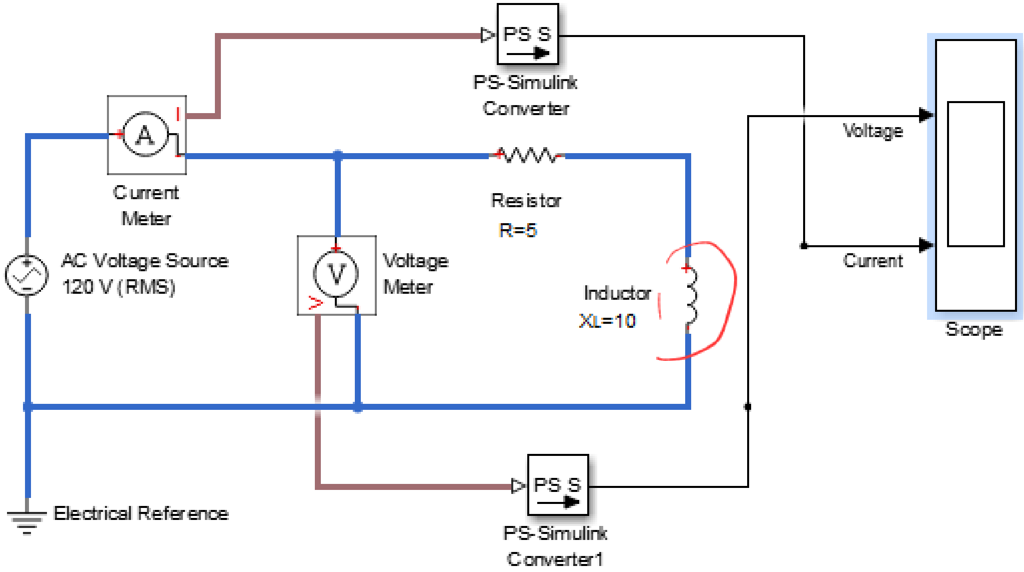


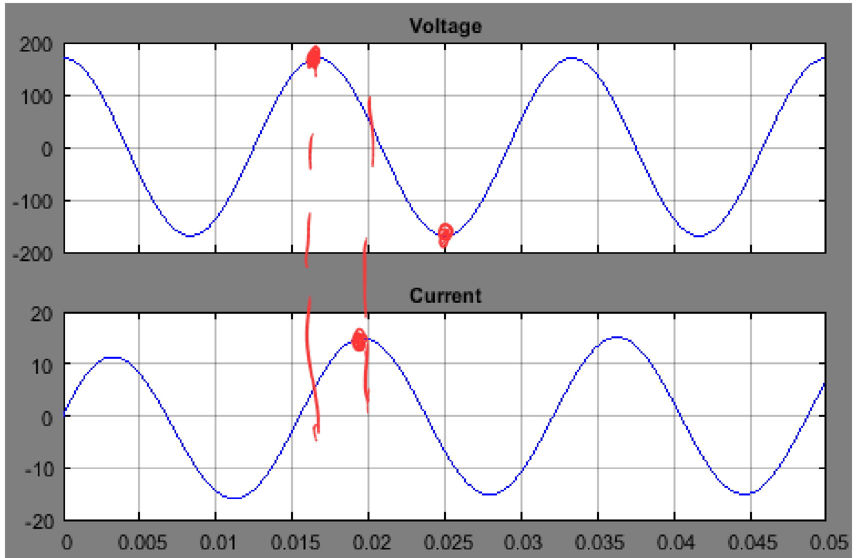
- Do the solution waveforms depend on initial conditions?

No

Steady-state Solution

$$v(t) = V_m \cos(\omega t)$$
$$i(t) = I_m \cos(\omega t + \varphi_i)$$



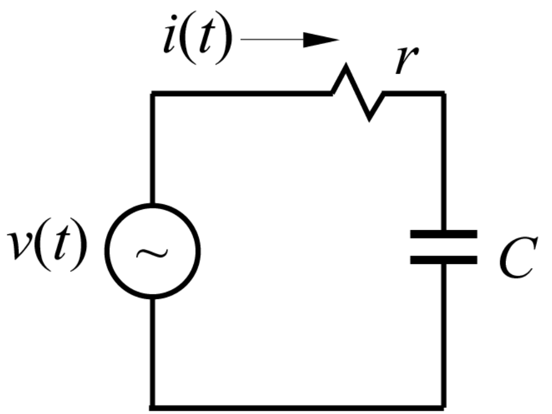


AC circuits

- Consider linear capacitive circuit

Capacitor can store energy $E_C = \frac{Cv^2}{2}$

- Where is this energy stored? → electric field
- Can the stored energy change instantaneously? → cap. voltage cannot change instantaneously



$$v(t) = V_m \cos(\omega t)$$

ODE

$$v(t) = ri + v_c$$

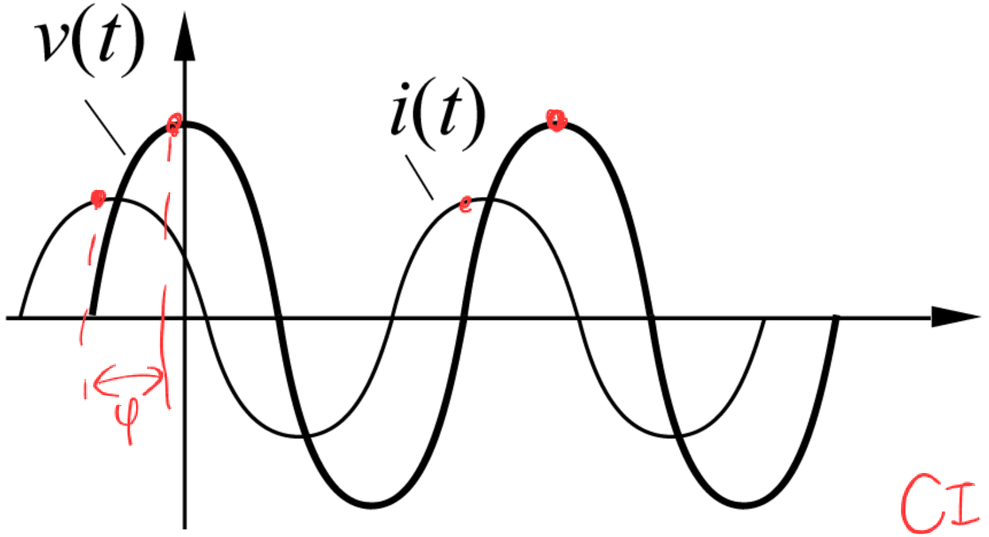
$$i = \frac{v - v_c}{r} = C\frac{dv_c}{dt}$$

$$C\frac{dv_c}{dt} + \frac{1}{r}v_c = \frac{1}{r}v(t)$$

Steady-state Solution

$$v_c(t) = V_{c,m}\cos(\omega t + \varphi_v)$$

$$i(t) = I_m \cos(\omega t + \varphi_i)$$



$\varphi = 90°$ in ideal scenarios

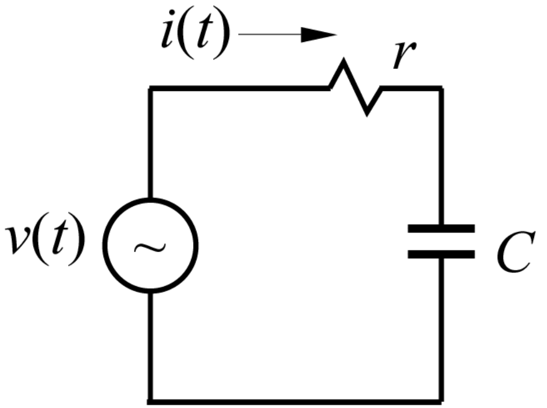
CIVIL

Note: For steady state, we need to know only amplitude & phase

AC circuits

- Consider linear capacitive circuit

Capacitor can store energy $E_C = \dfrac{Cv^2}{2}$

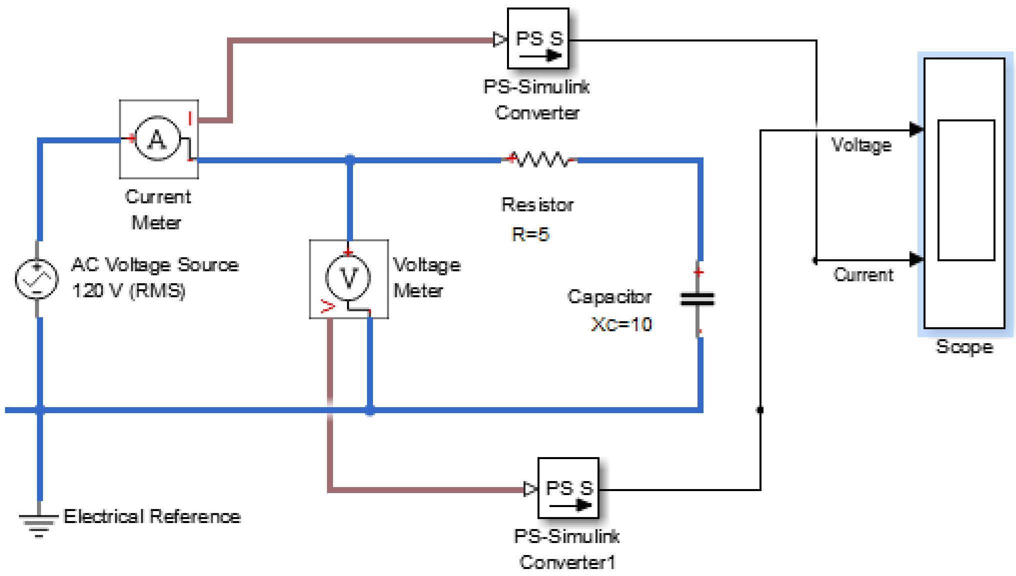


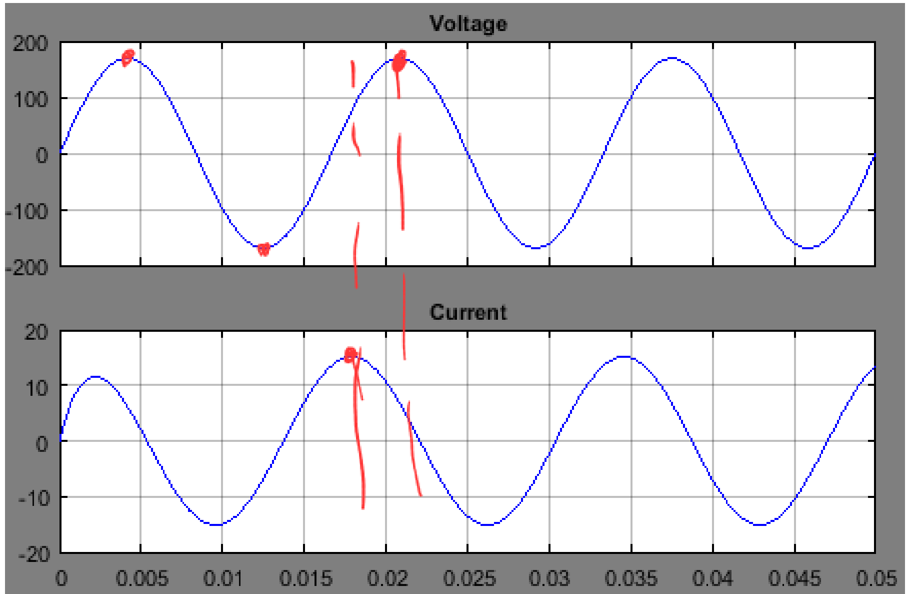
- Do the solution waveforms depend on initial conditions?

No

Steady-state Solution

$$v(t) = V\cos(\omega t)$$
$$i(t) = I_m \cos(\omega t + \varphi_i)$$

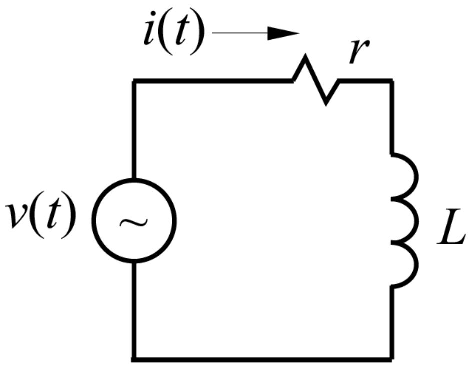




AC circuits

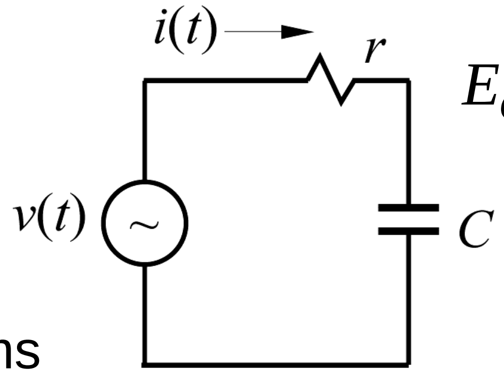
- Consider linear RLC circuit

$$v(t) = V_m \cos(\omega t)$$



delays current

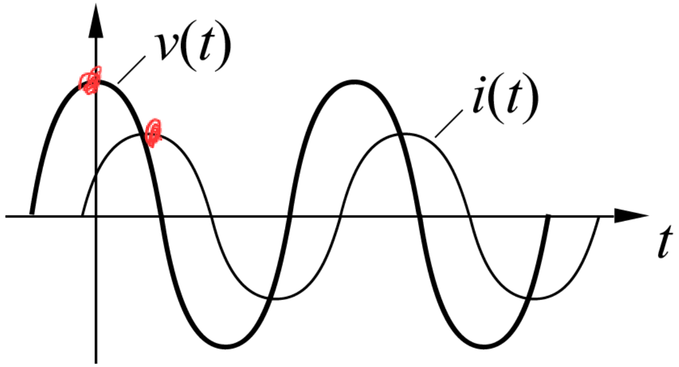
$$E_L = \frac{Li^2}{2}$$

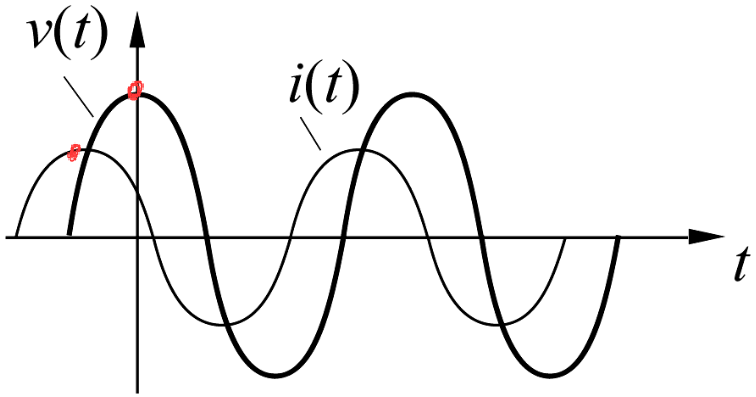


$$E_C = \frac{Cv^2}{2}$$

delays voltage

Steady state waveforms





Note: Inductors and capacitors can store energy.
In both cases, for steady state analysis, we need to know only amplitude & phase → no need to know initial conditions

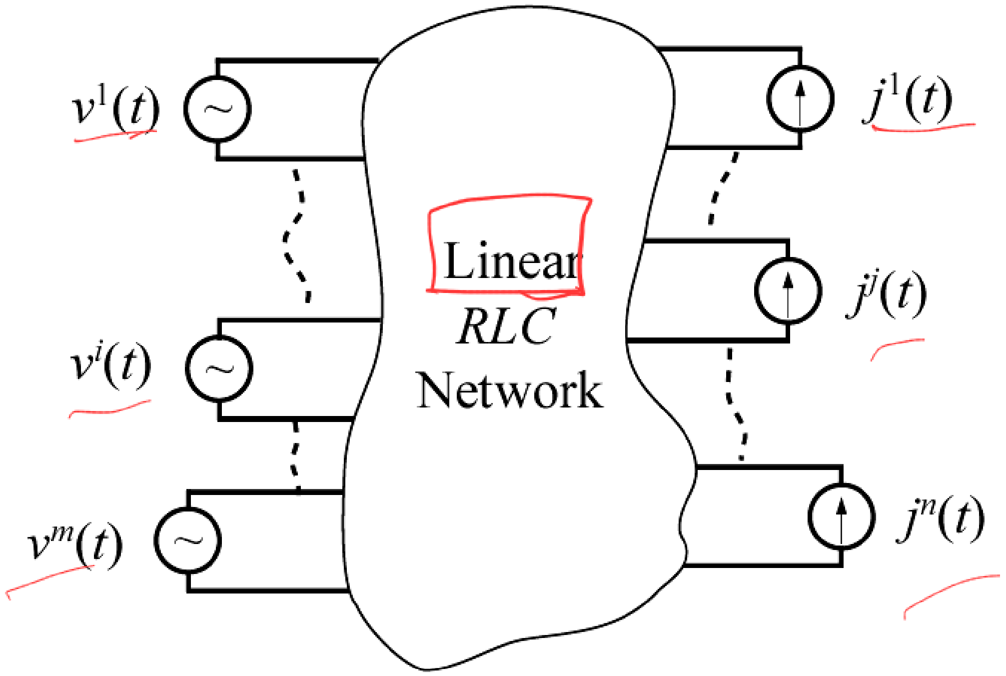
AC circuits

- Consider arbitrary network
  - With voltage and current sources

fixed frequency

$$v^i(t) = V^i \cos(\omega t + \varphi^i)$$

$$j^j(t) = J^j \cos(\omega t + \varphi^j)$$



Steady state solution?

For all circuit branches the currents & voltages are sinusoidal

$$i_k(t) = I_k \cos(\omega t + \theta_i^k)$$

$$v_k(t) = V_k \cos(\omega t + \theta_v^k)$$

Note:

For Steady State analysis we need to know only amplitudes J^k, V^k & phases θ_i^k, θ_v^k

Looking ahead…

- Module 1, part 1 continued