

ENERGY 101

Session 1: Synchronous Machines

Carnegie Mellon Electric Energy Club

Ellery Blood

10 April 2009 : HBH 1003

2:00 pm – 3:30 pm

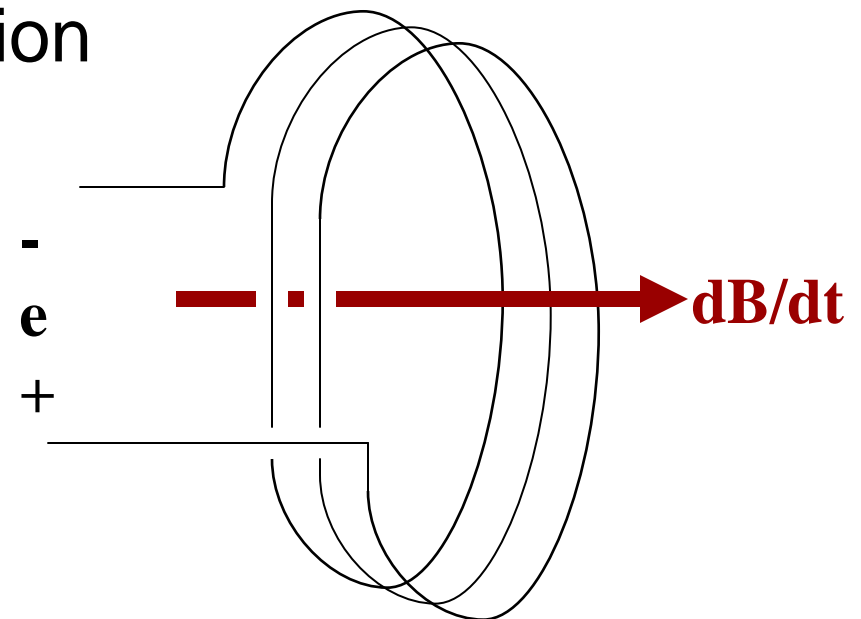
Outline

- Synchronous Generator Fundamentals
- Generator and Load
- Generator and Generator

Synchronous Generator Fundamentals

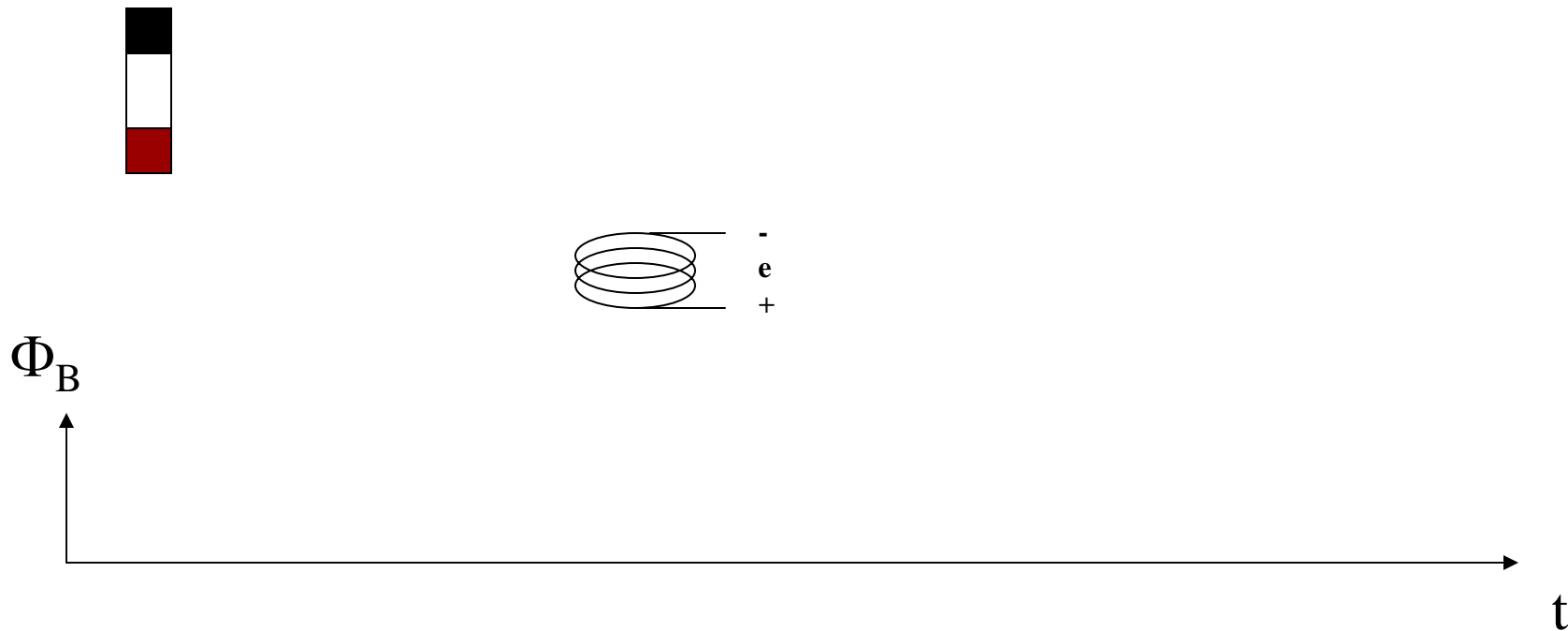
- Faraday's law of induction

$$e = -\frac{d}{dt}\Phi_B$$



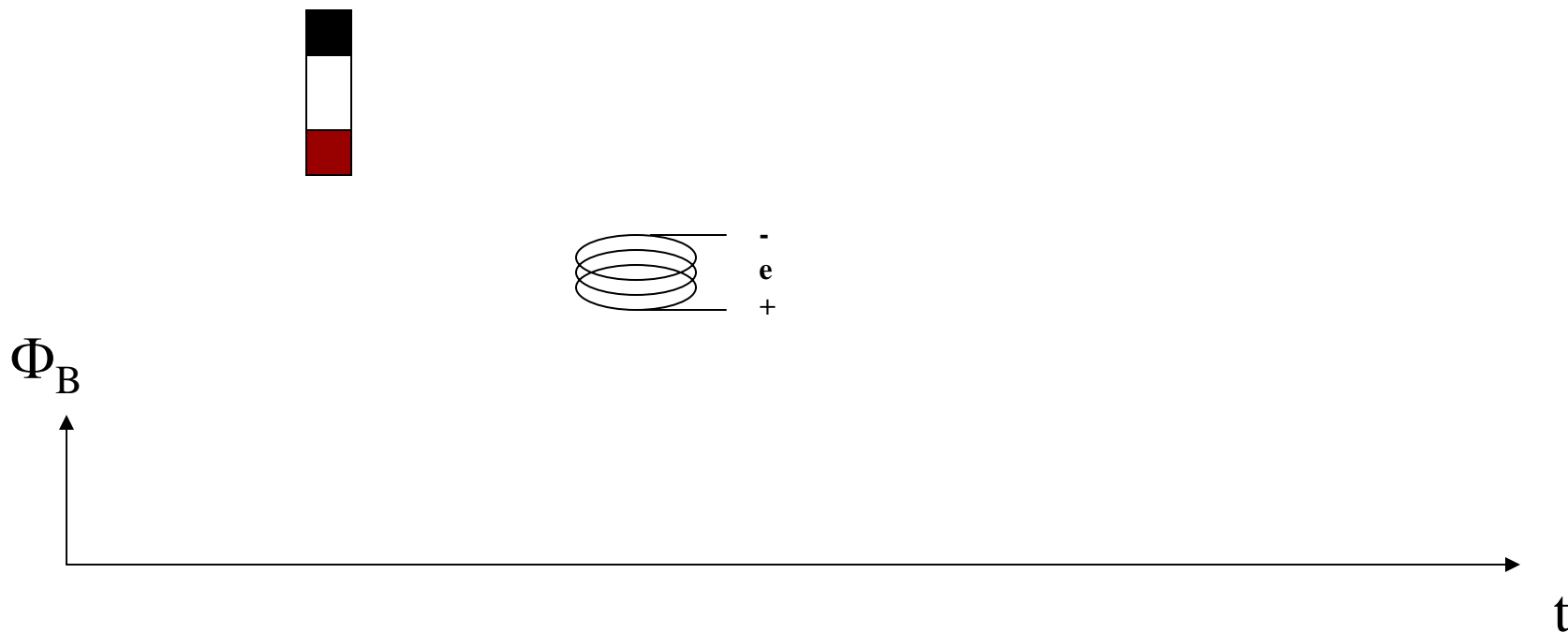
Synchronous Generator Fundamentals

- Magnet passing over a coil



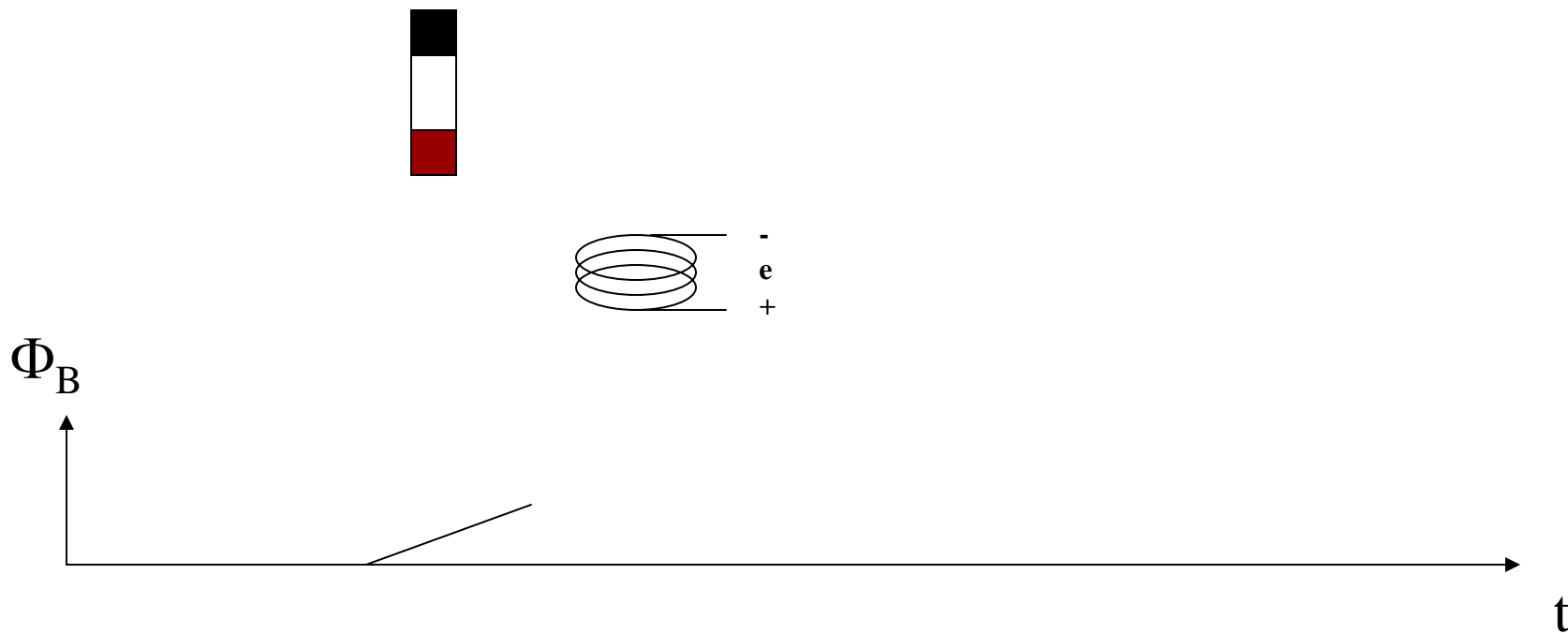
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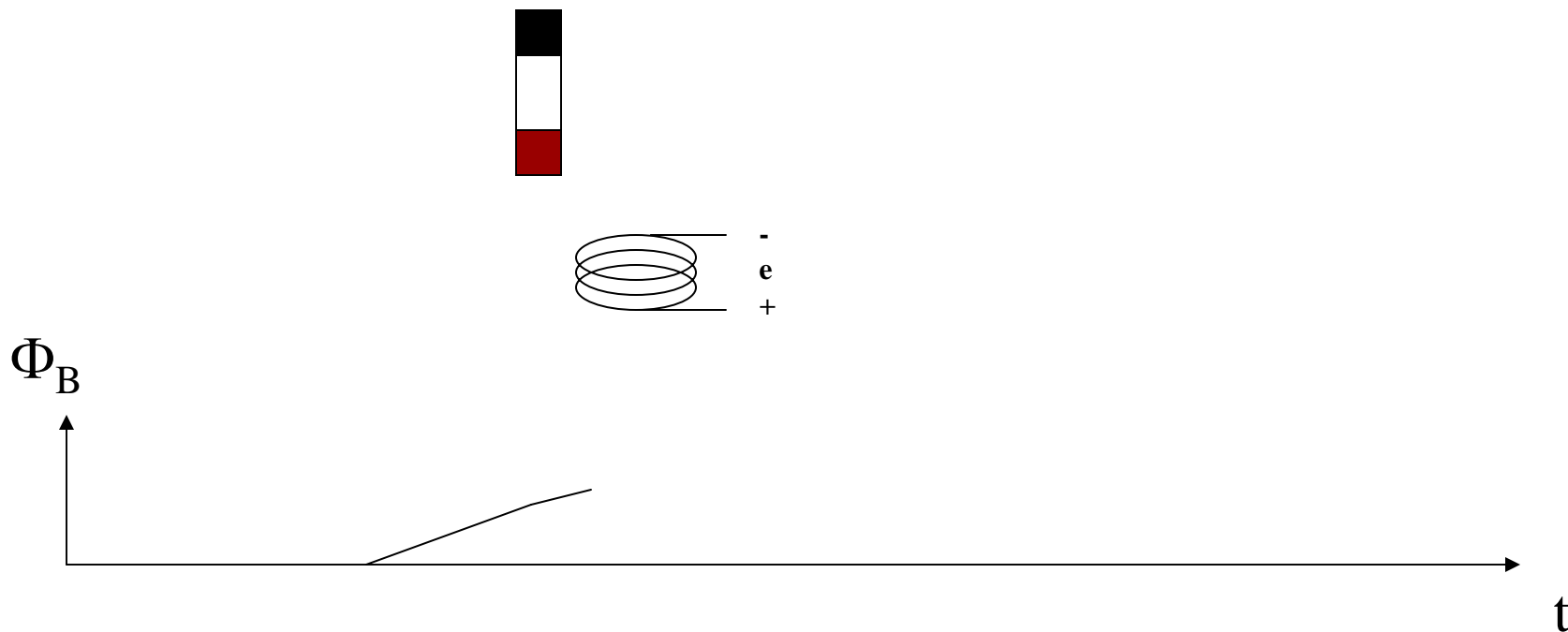
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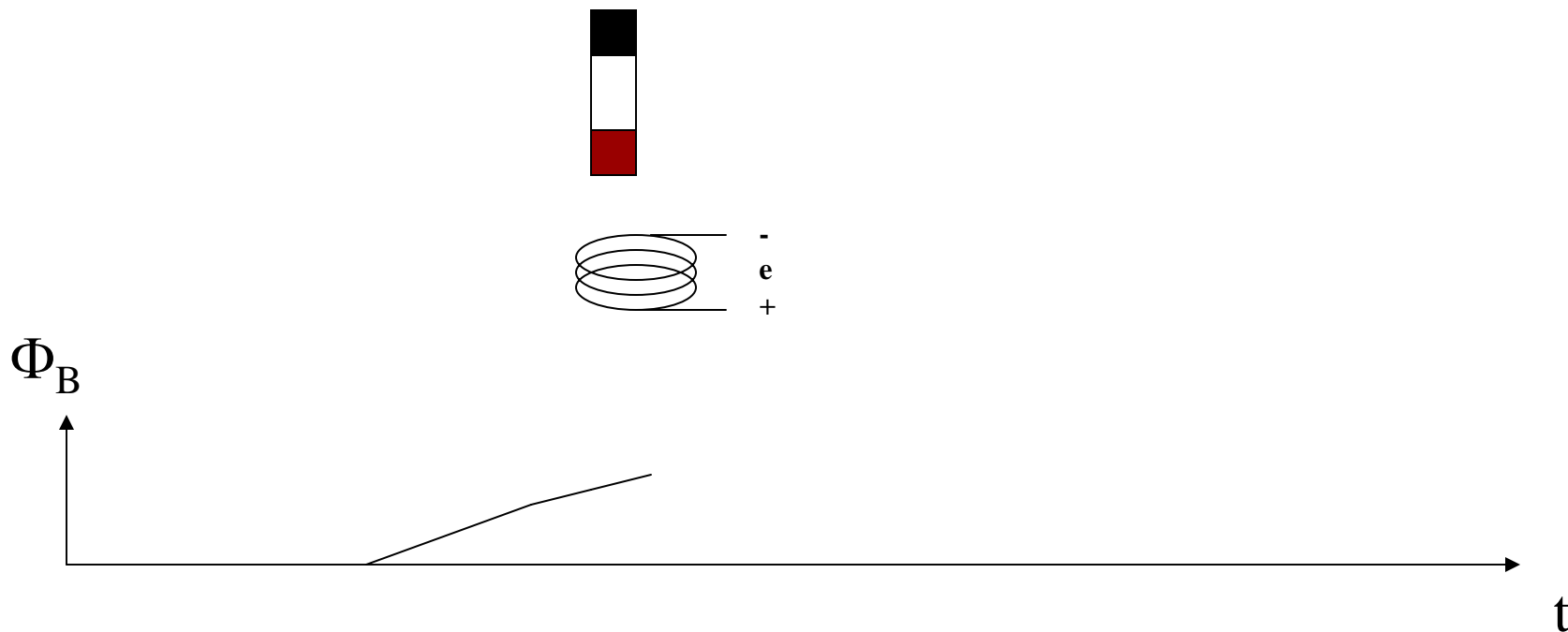
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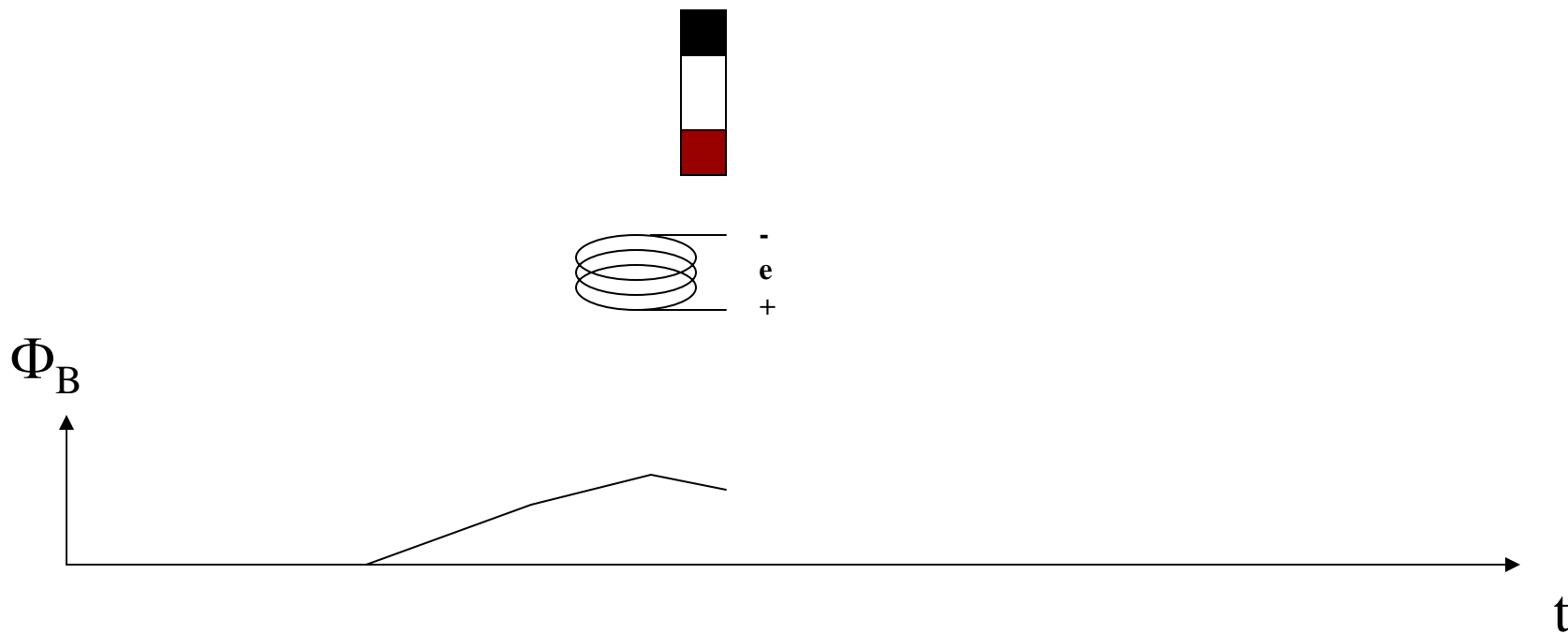
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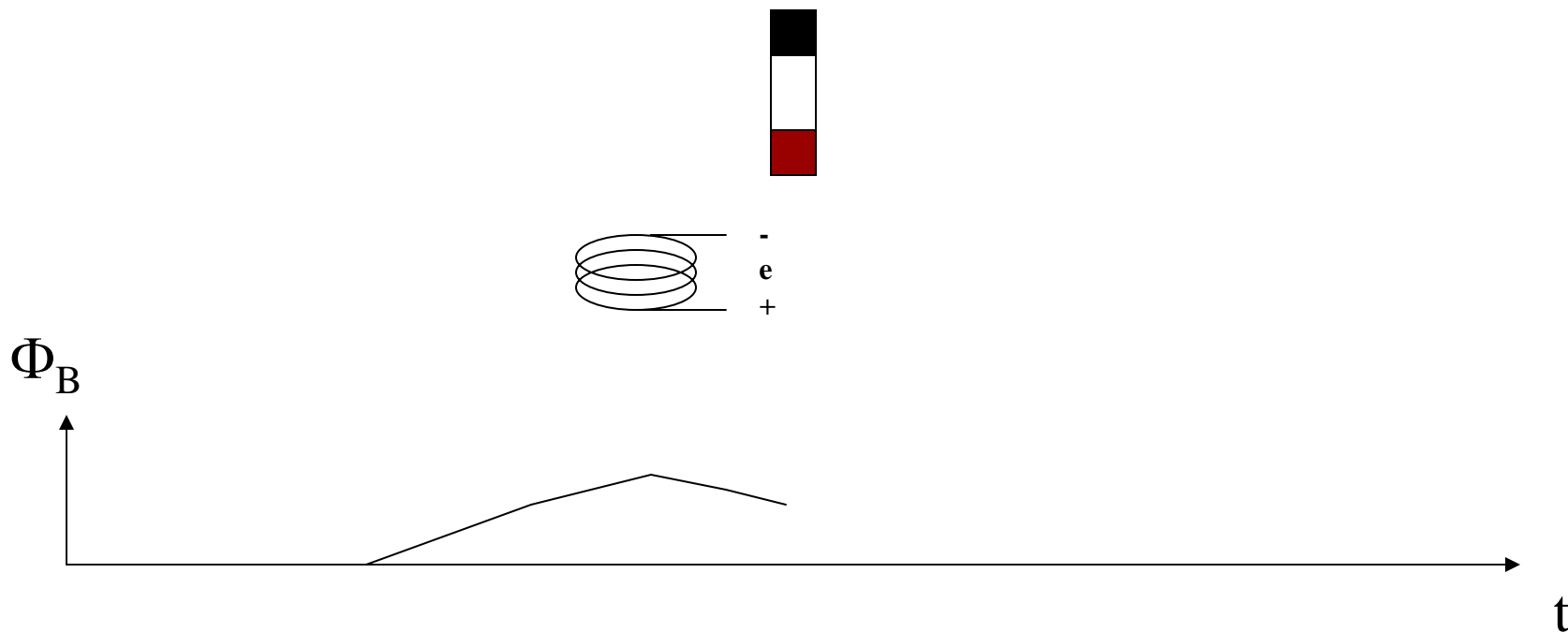
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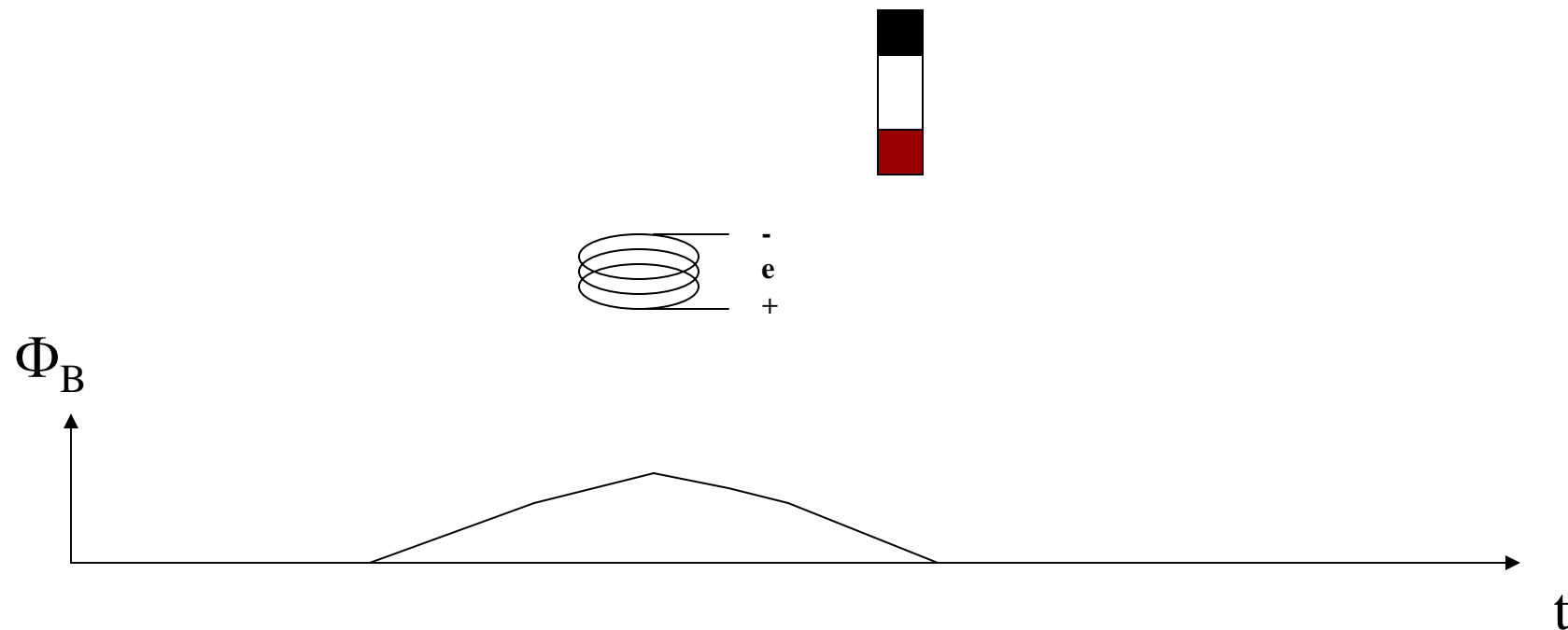
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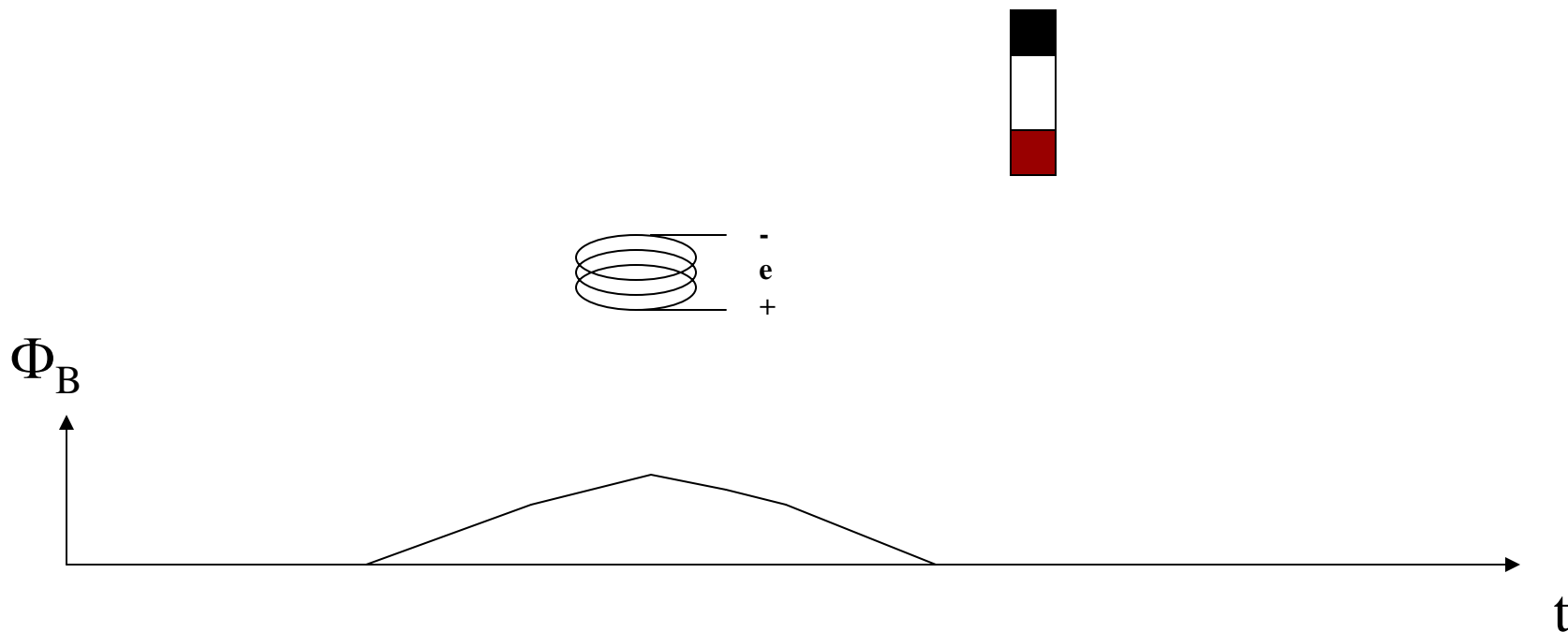
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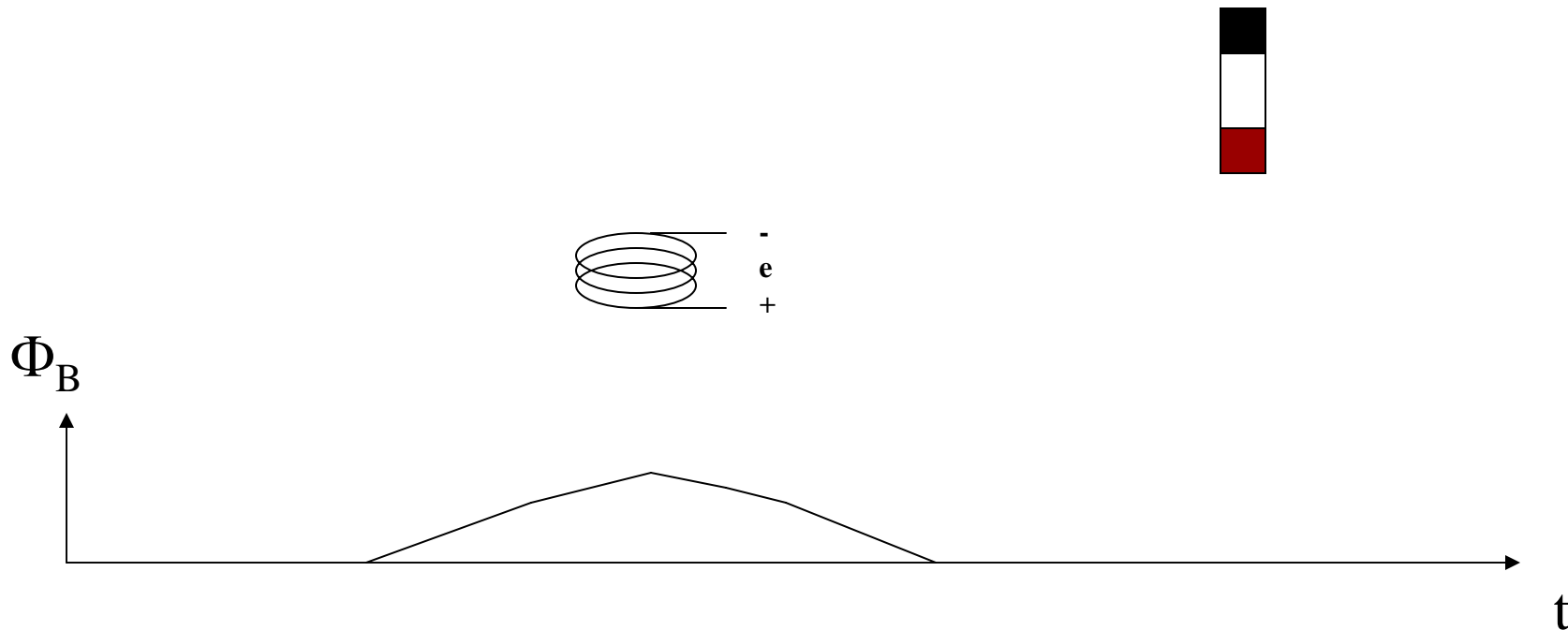
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Synchronous Generator Fundamentals

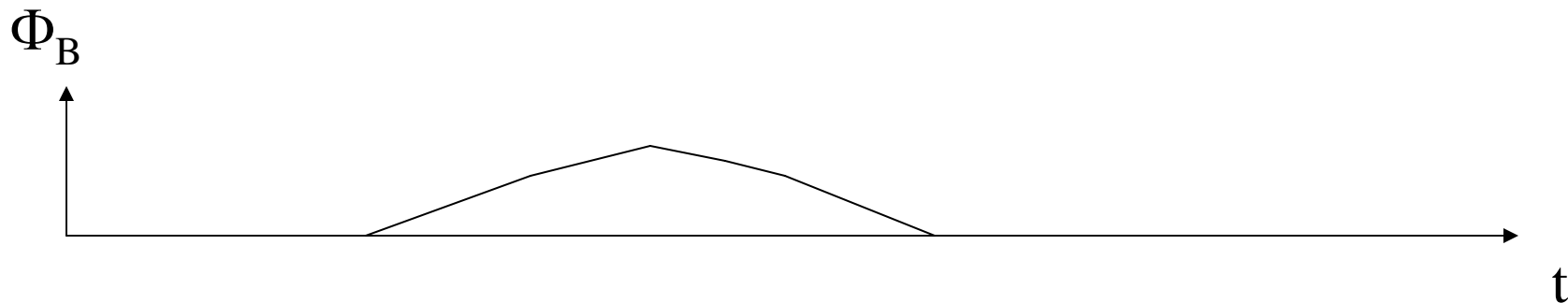
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Synchronous Generator Fundamentals

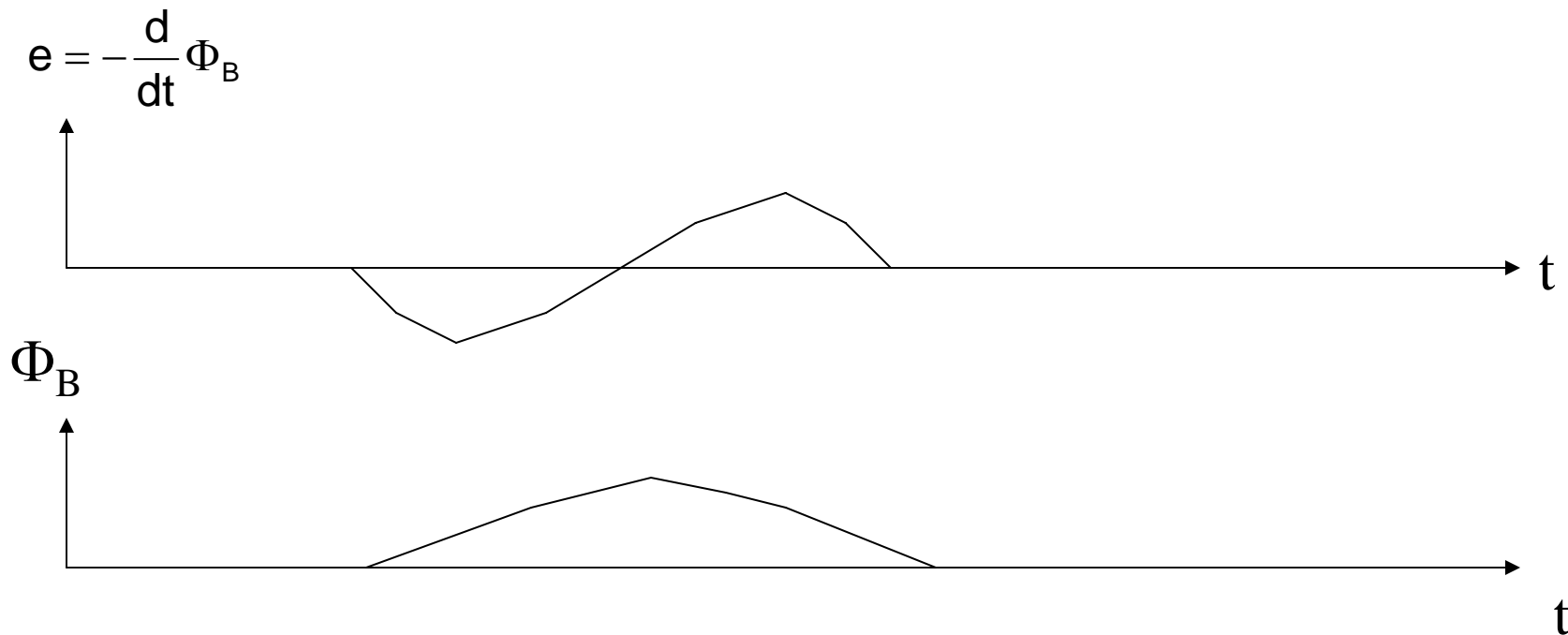
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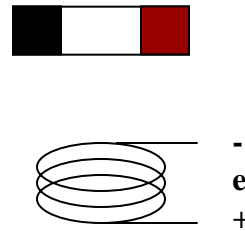
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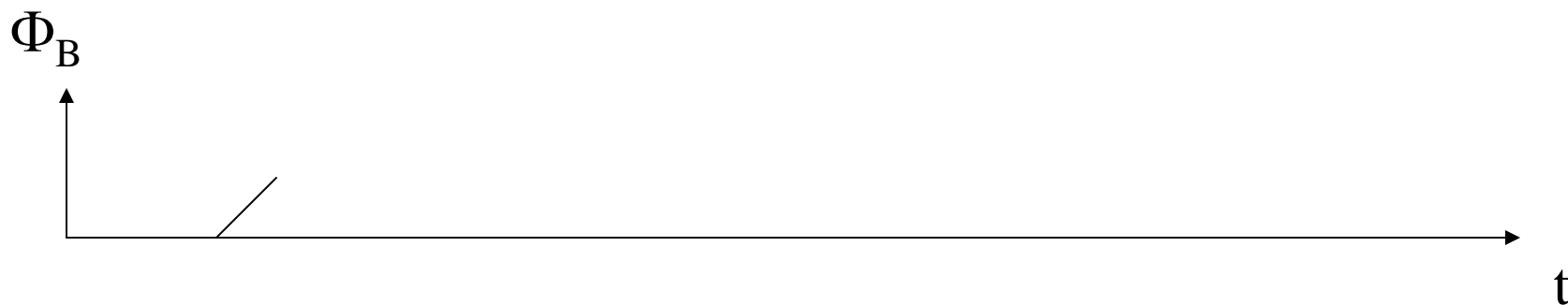
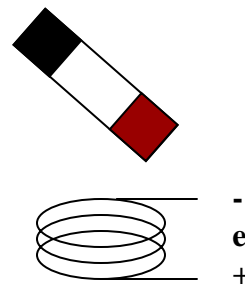
Synchronous Generator Fundamentals

- Rotating Magnet near a coil



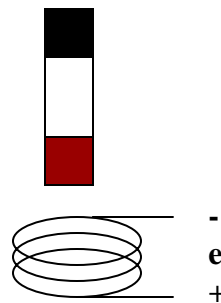
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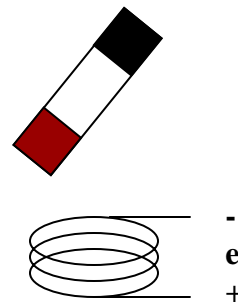
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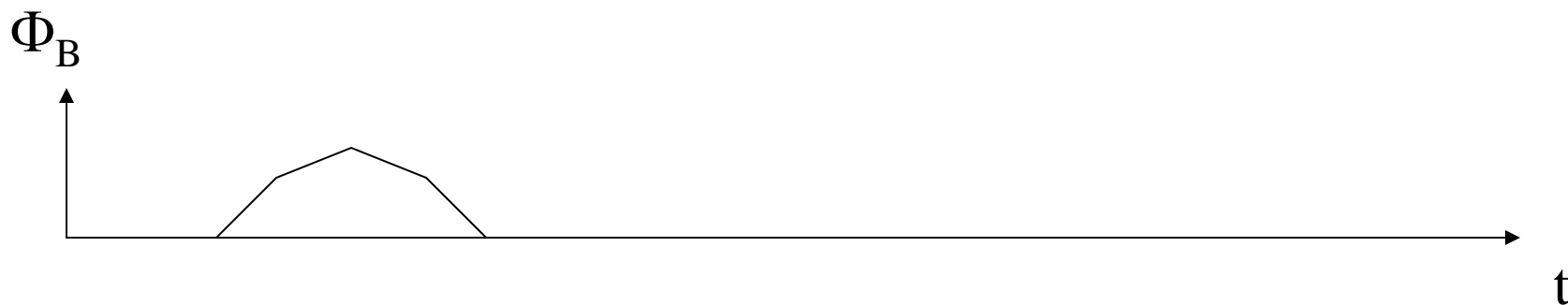
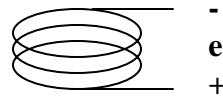
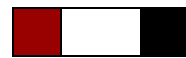
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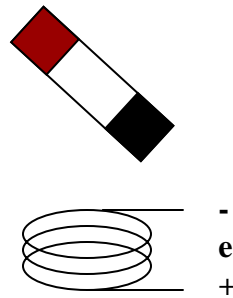
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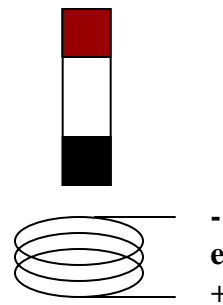
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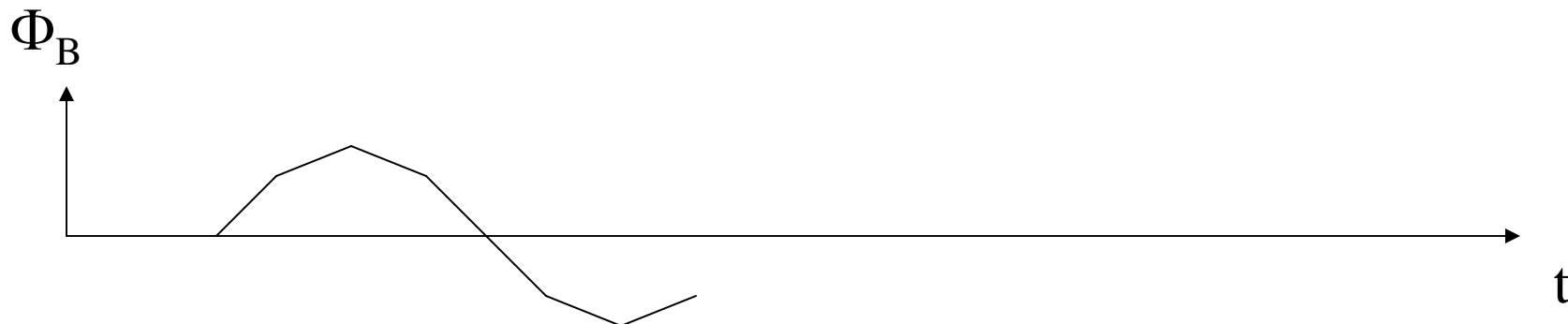
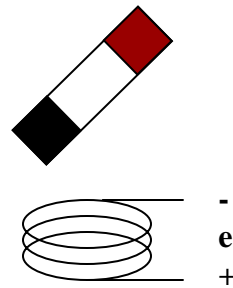
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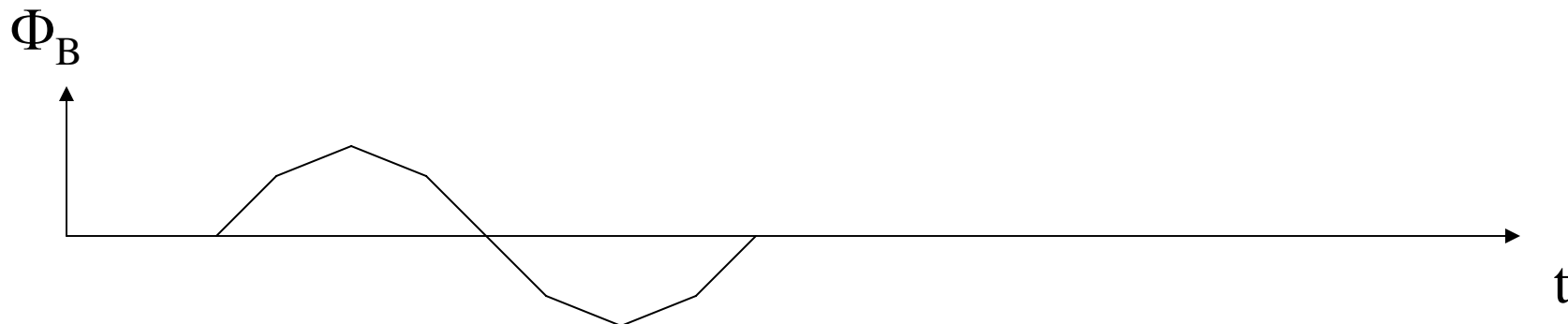
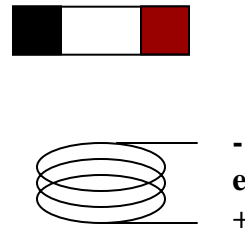
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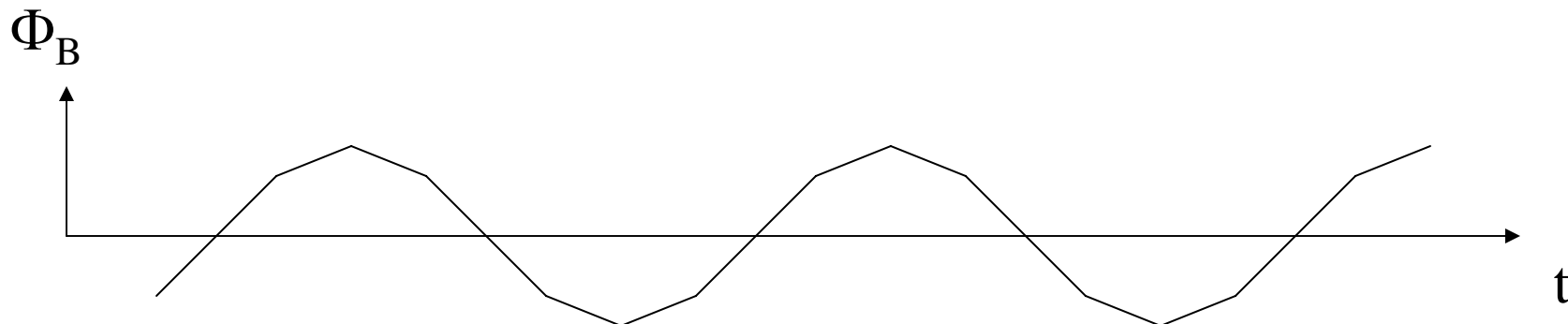
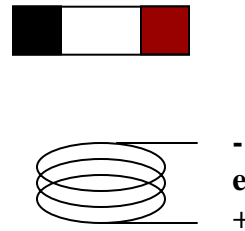
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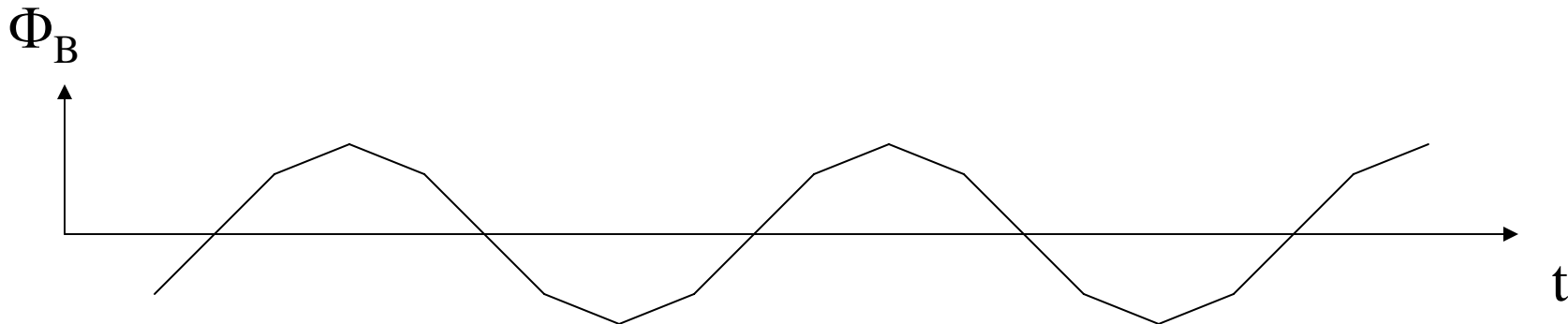
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Synchronous Generator Fundamentals

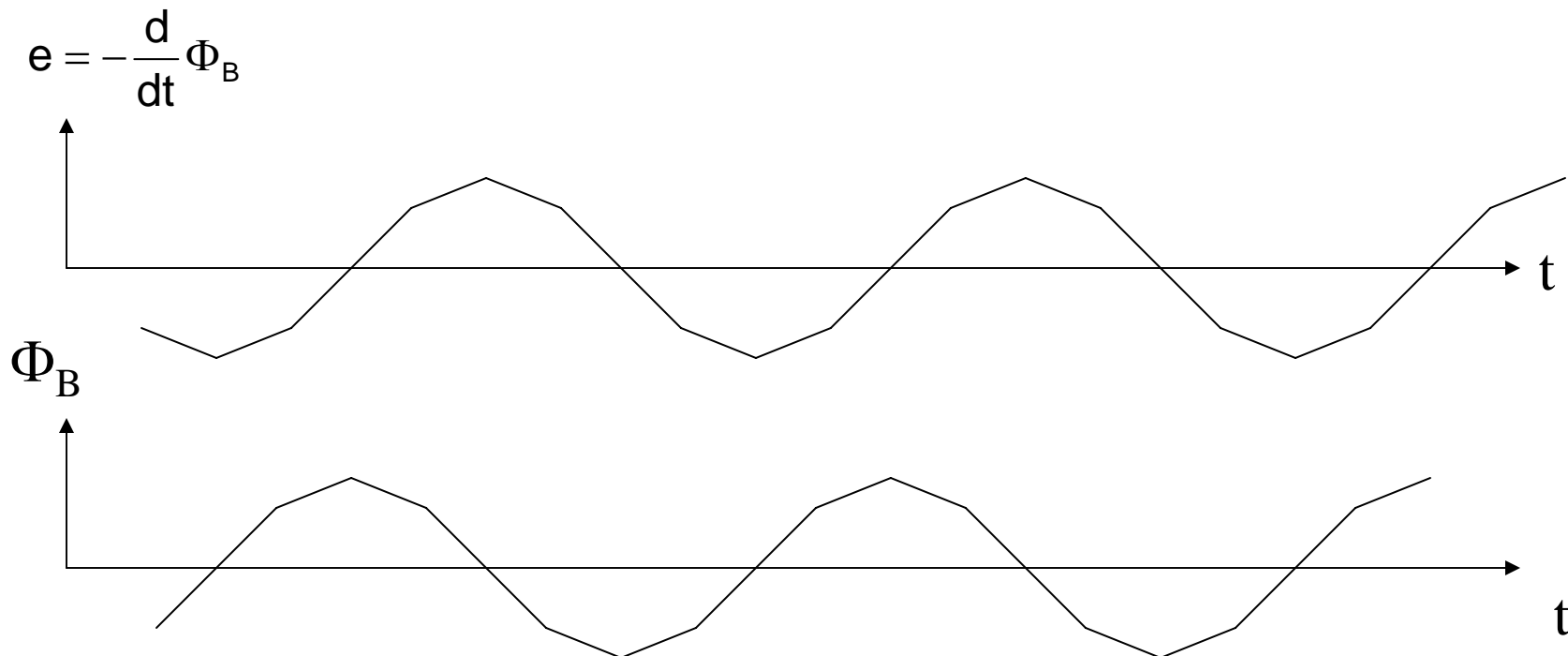
- Rotating Magnet near a coil

$$e = -\frac{d}{dt} \Phi_B$$



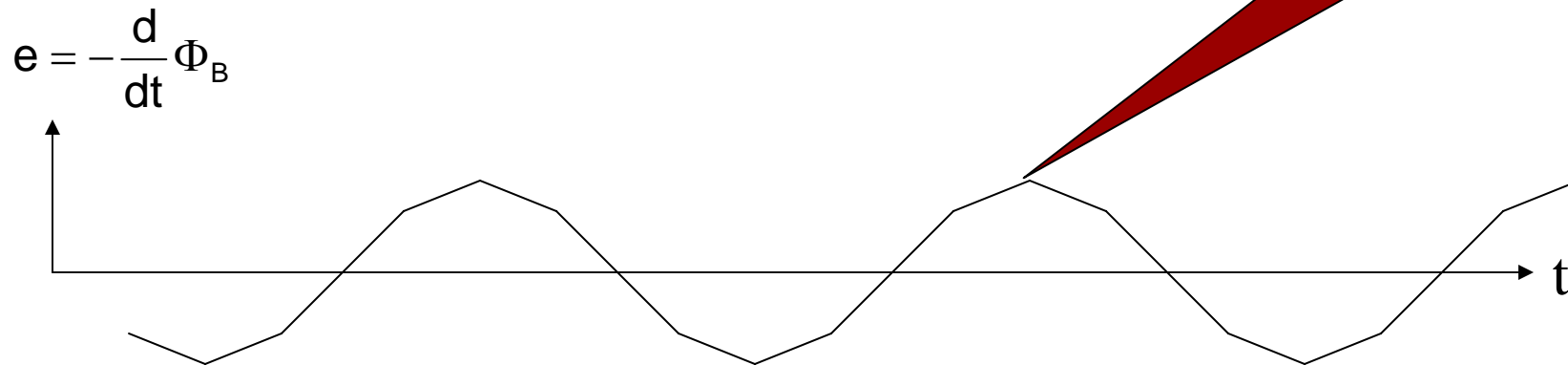
Synchronous Generator Fundamentals

- Rotating Magnet near a coil



Synchronous Generator Fundamentals

- Rotating Magnet near a coil



AC Generator

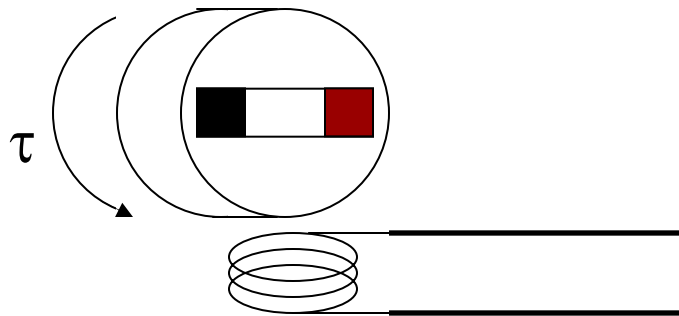
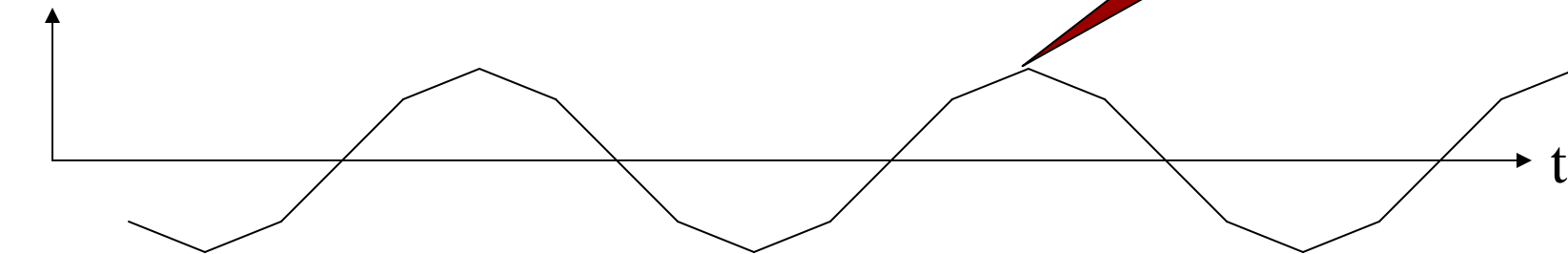


Synchronous Generator Fundamentals

- Rotating Magnet near a coil

$$e = -\frac{d}{dt} \Phi_B$$

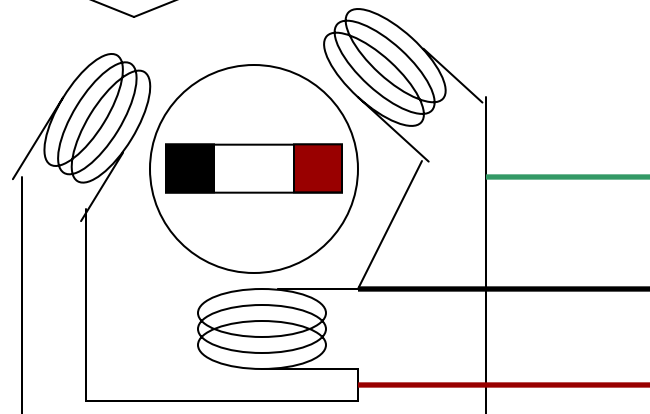
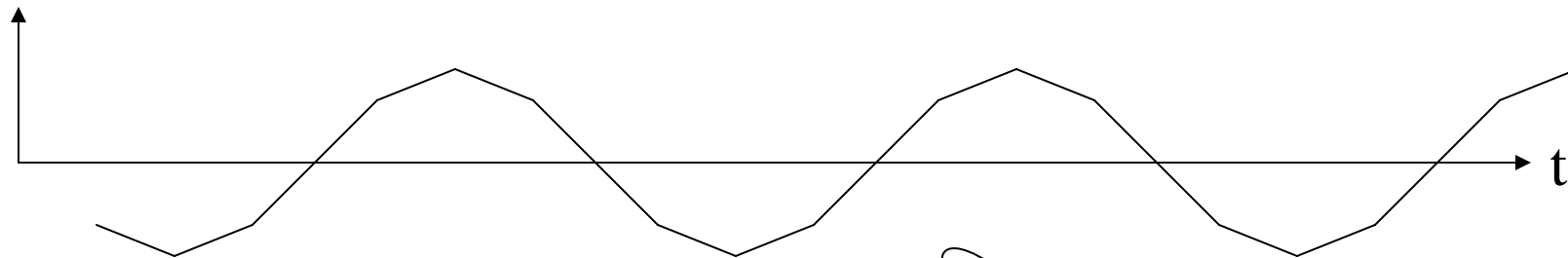
AC Generator



Synchronous Generator Fundamentals

- Rotating Magnet near a coil

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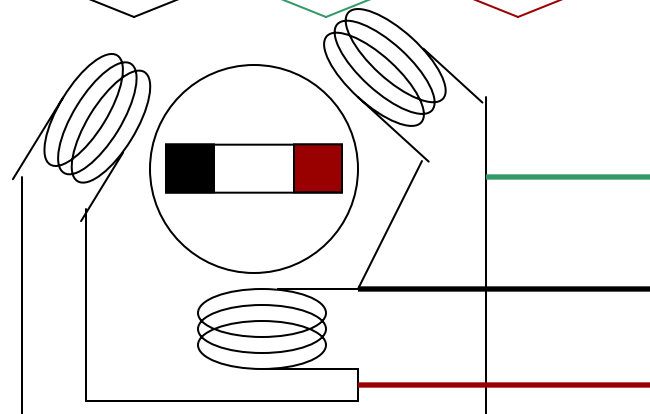
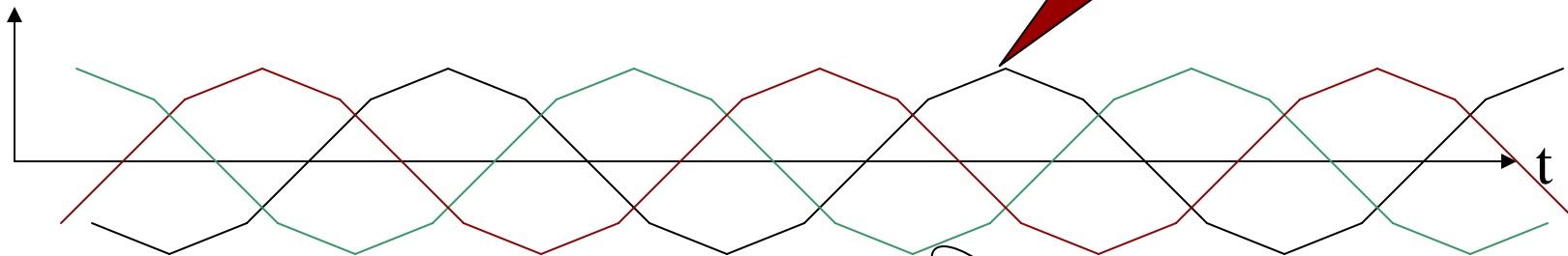


Synchronous Generator Fundamentals

- Rotating Magnet near a coil

3-phase AC Generator

$$e = -\frac{d}{dt} \Phi_B$$



Synchronous Generator Variables

- Rotating Magnet near a coil
- Torque to rotate magnet (prime mover)
 - Steam turbine
 - Internal combustion
 - Hydro
 - Wind
- Use electro-magnet instead of PM

Synchronous Generator Variables

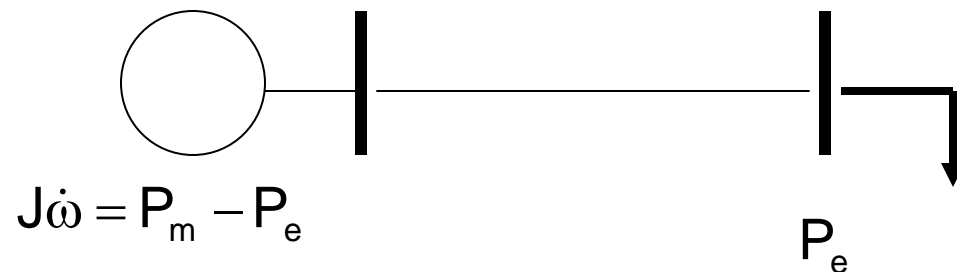
- Electro magnet strength (field current)
 - Affects electrical torque (τ_e)
 - Voltage Magnitude (v)
- Prime mover
 - Affects mechanical torque (τ_m)
 - Frequency (ω)
- Power
 - $P_e = \omega \tau_e$

Outline

- Synchronous Generator Fundamentals
- Generator and Load
- Generator and Generator

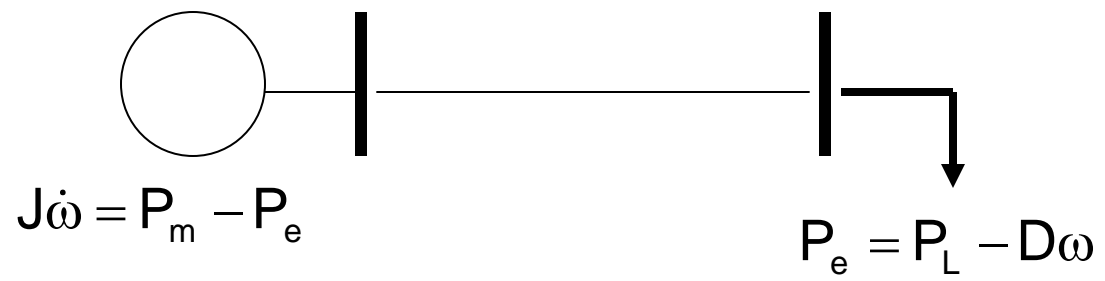
Generator and Load

- Generation follows load



Generator and Load

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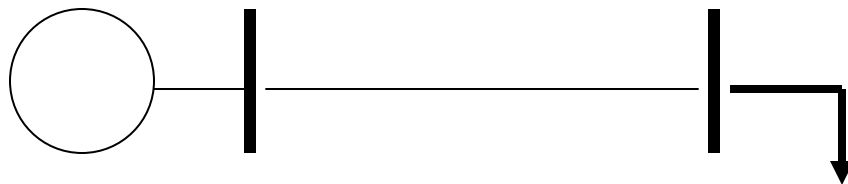
Generator and Load

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Generator and Load

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$$J\dot{\omega} = P_m - P_e$$

$$\dot{a} = k(\omega - \omega_0)$$

$$\dot{P}_m = a - \beta P_m$$

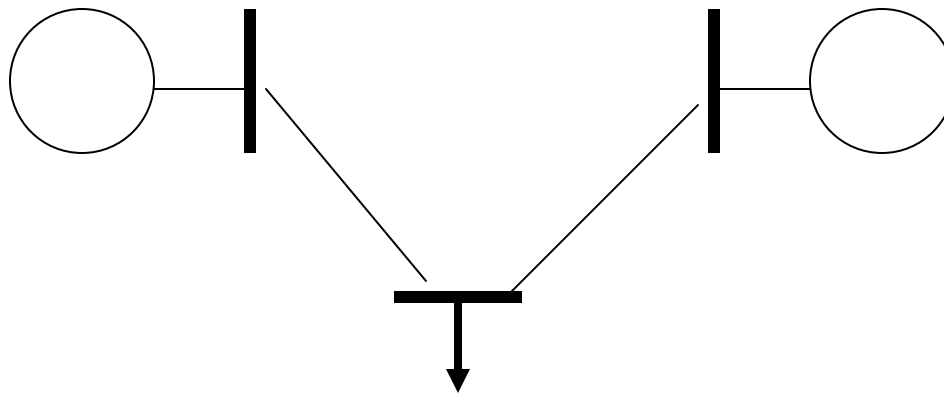
$$P_e = P_L - D\omega$$

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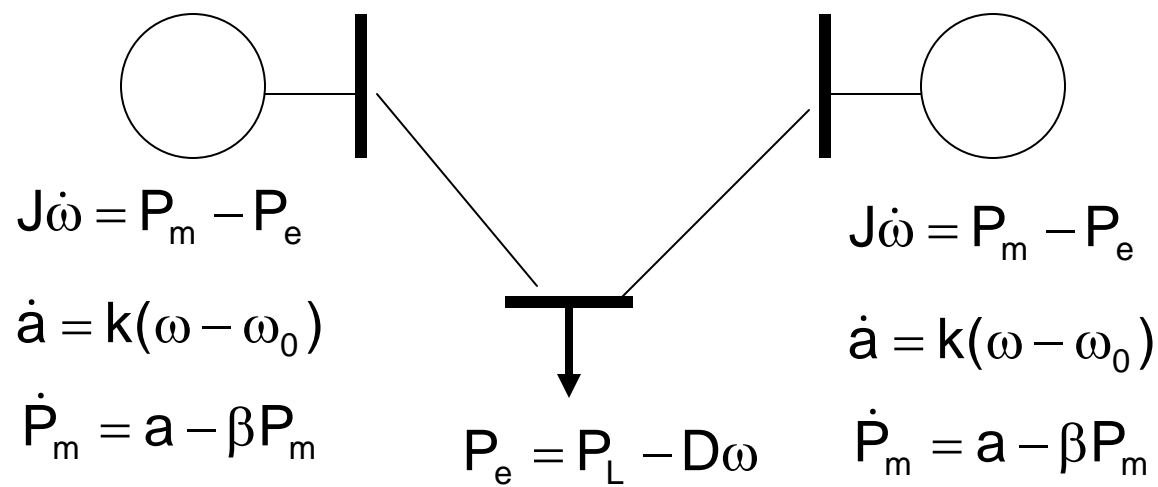
2 Generators and Load

- Generation follows load



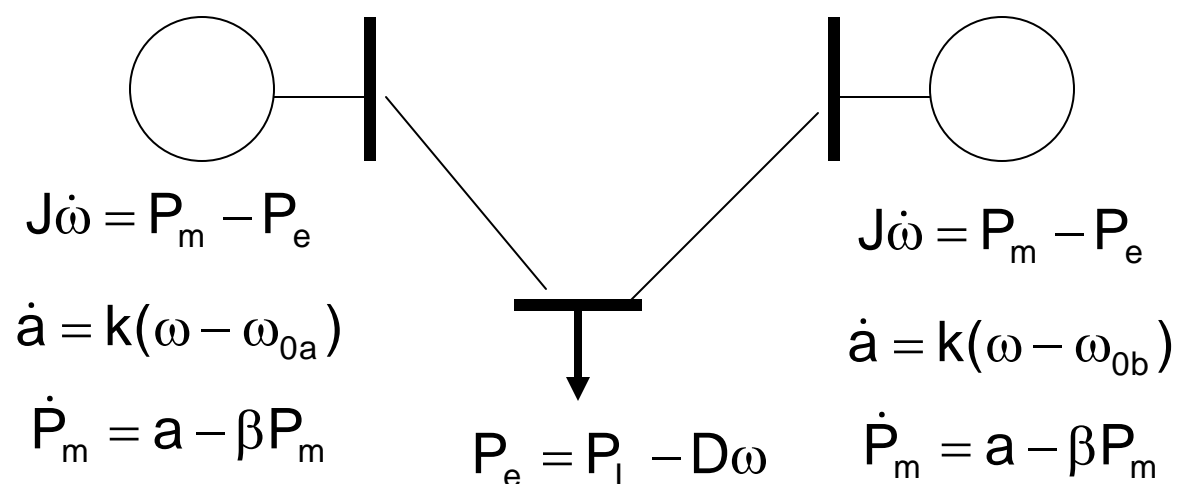
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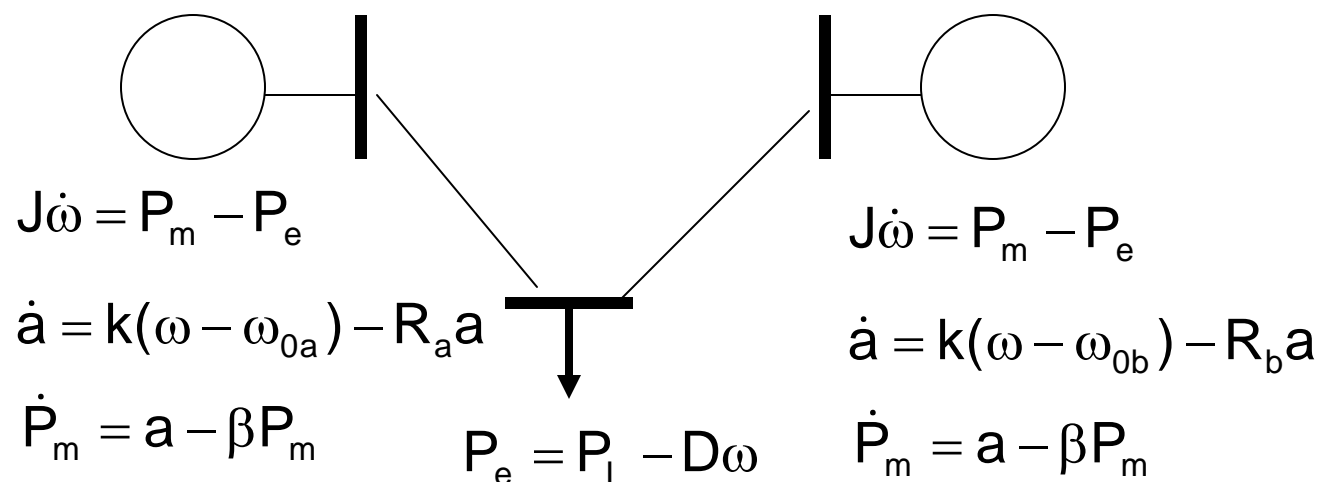
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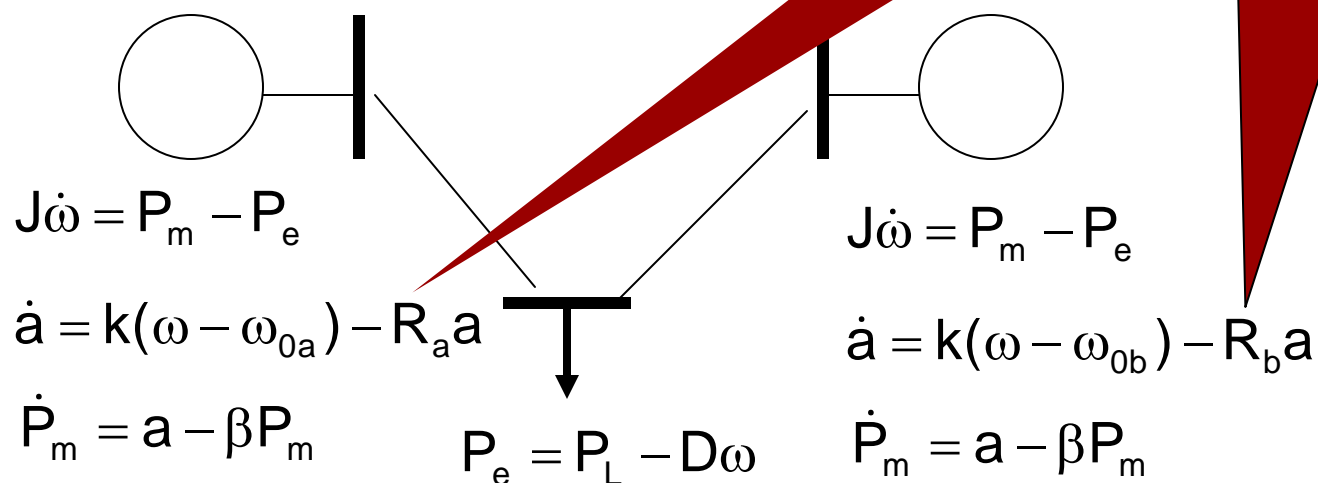
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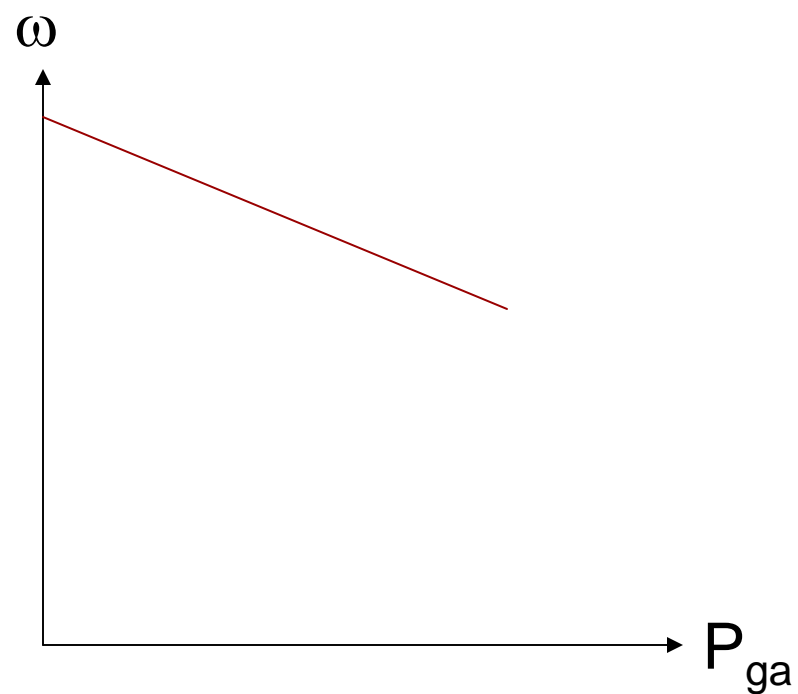


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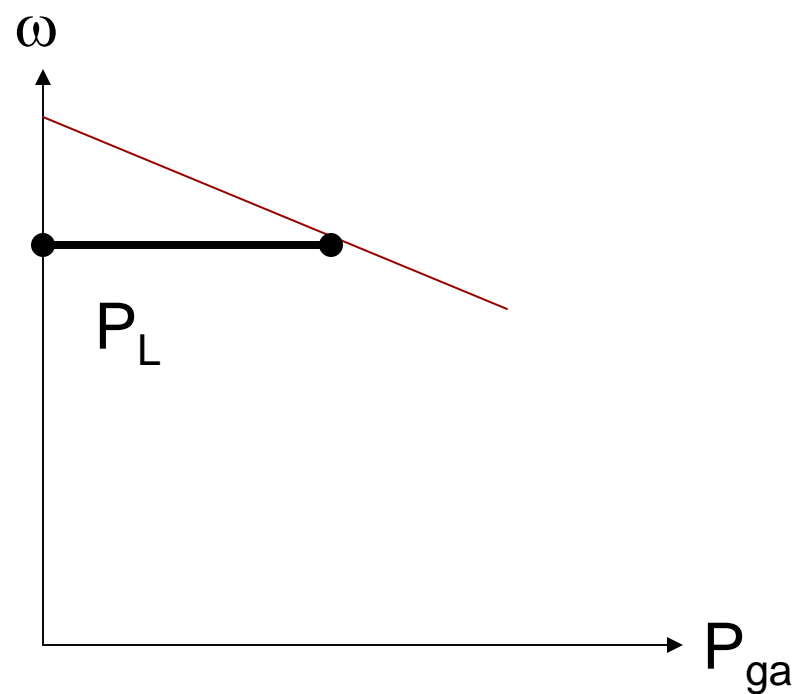
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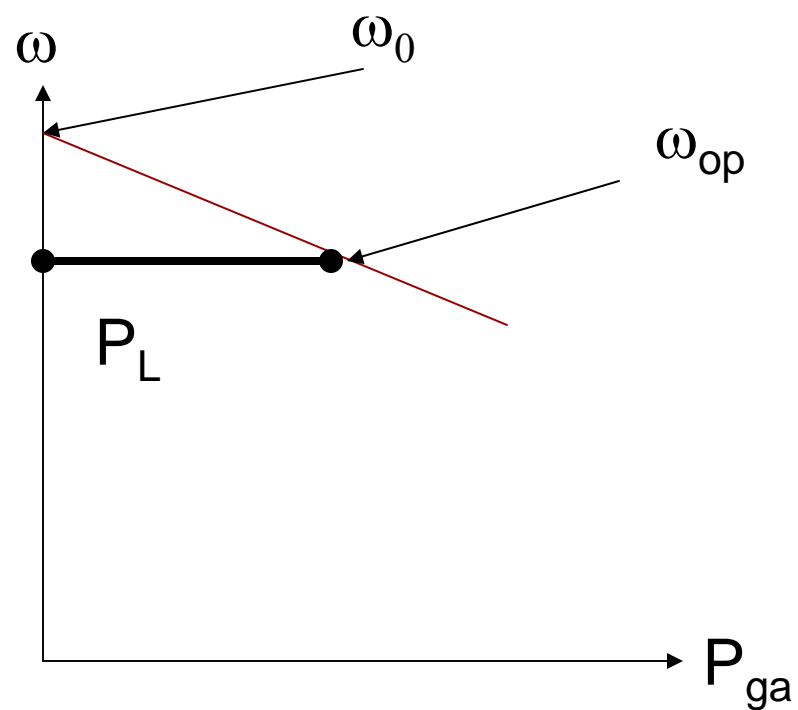
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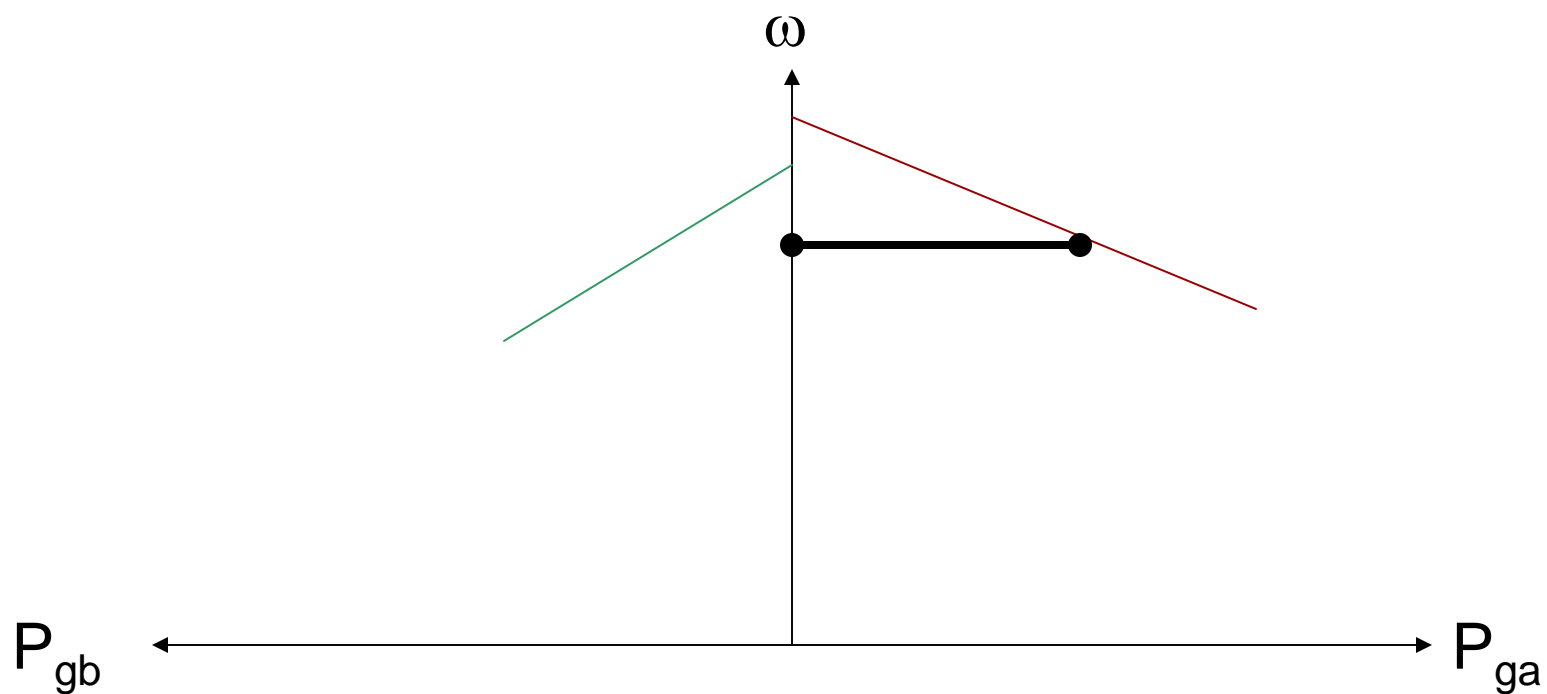
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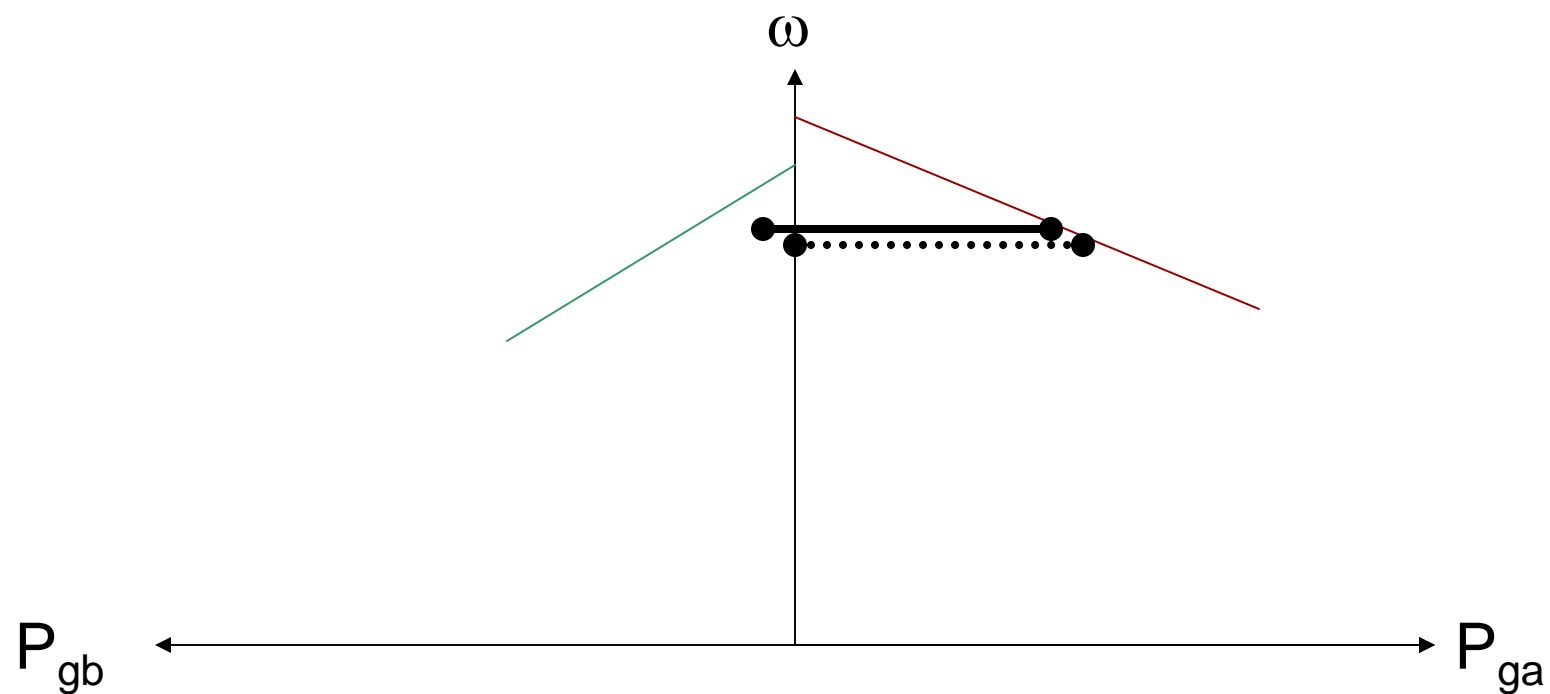
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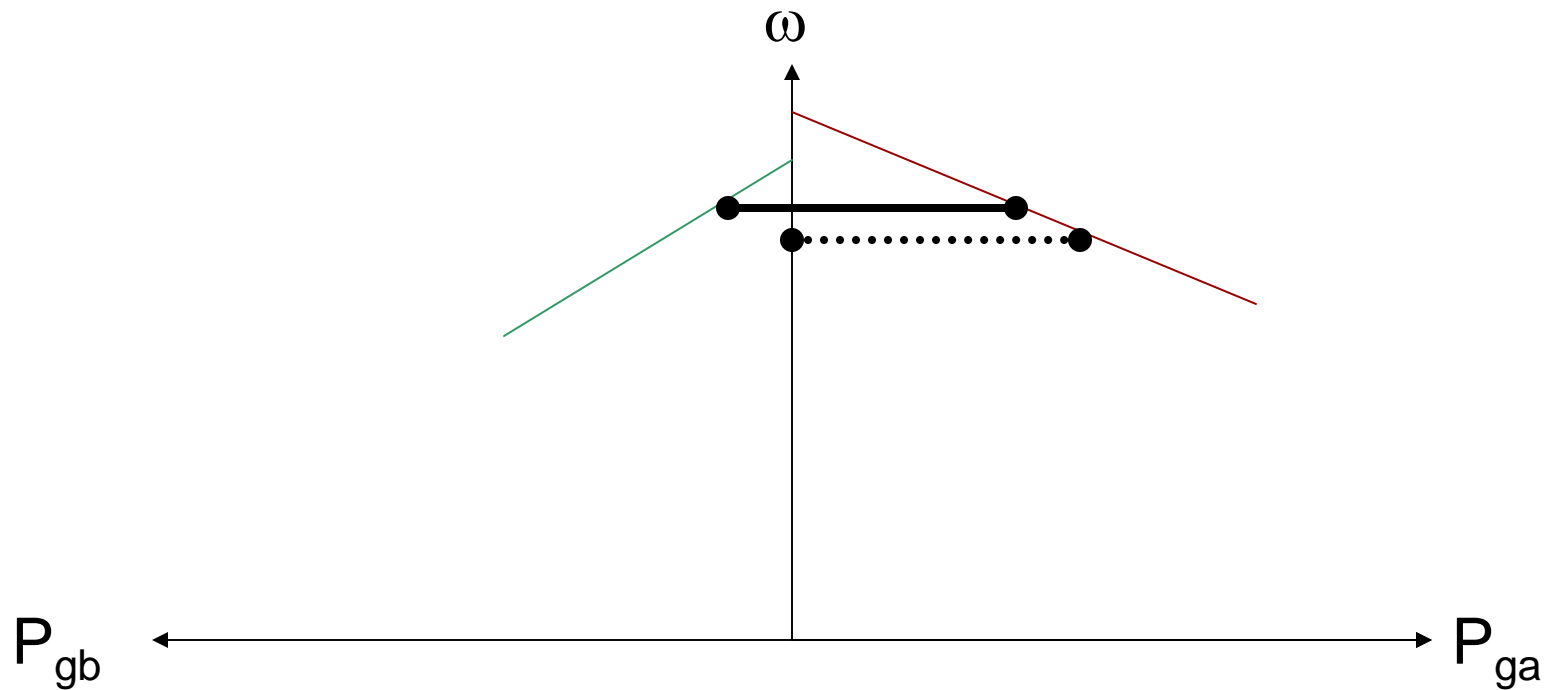
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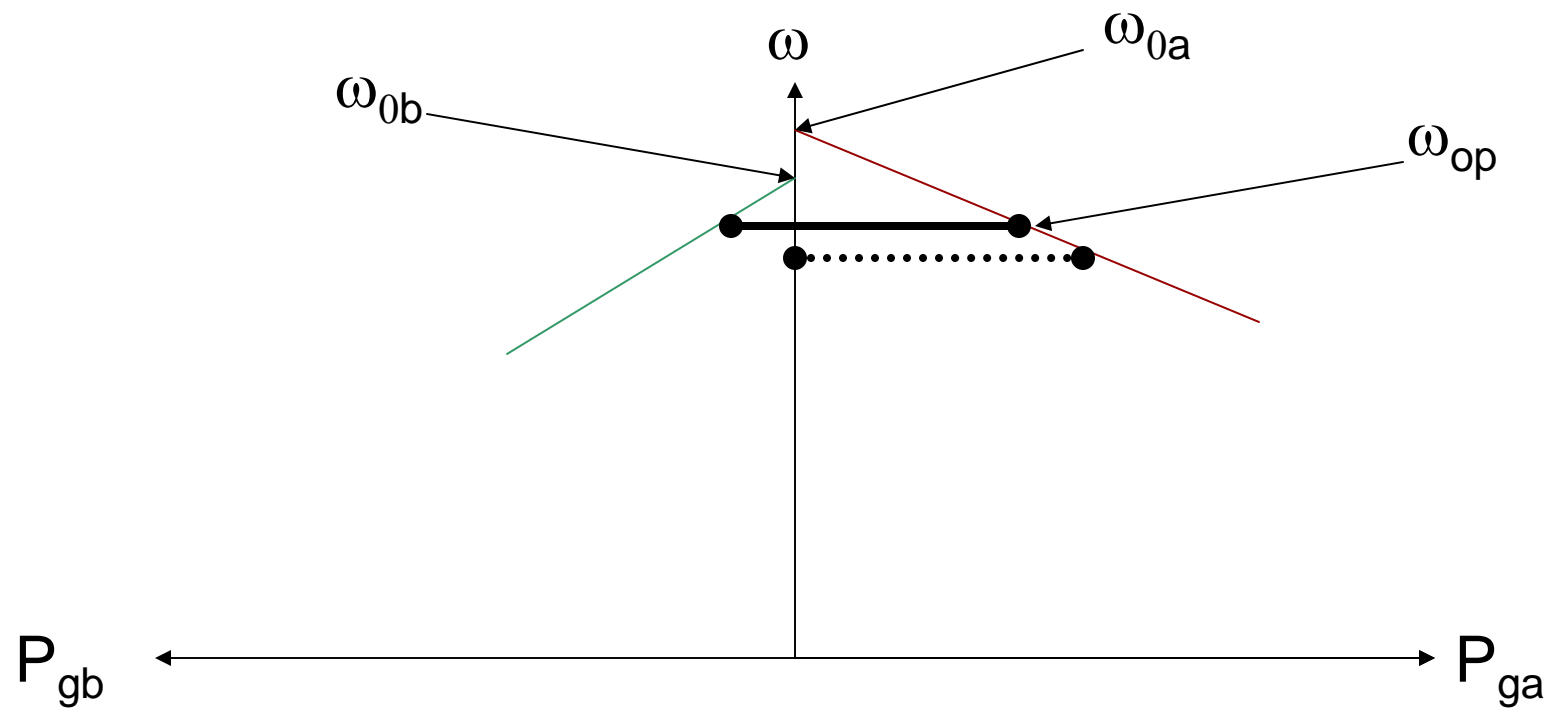
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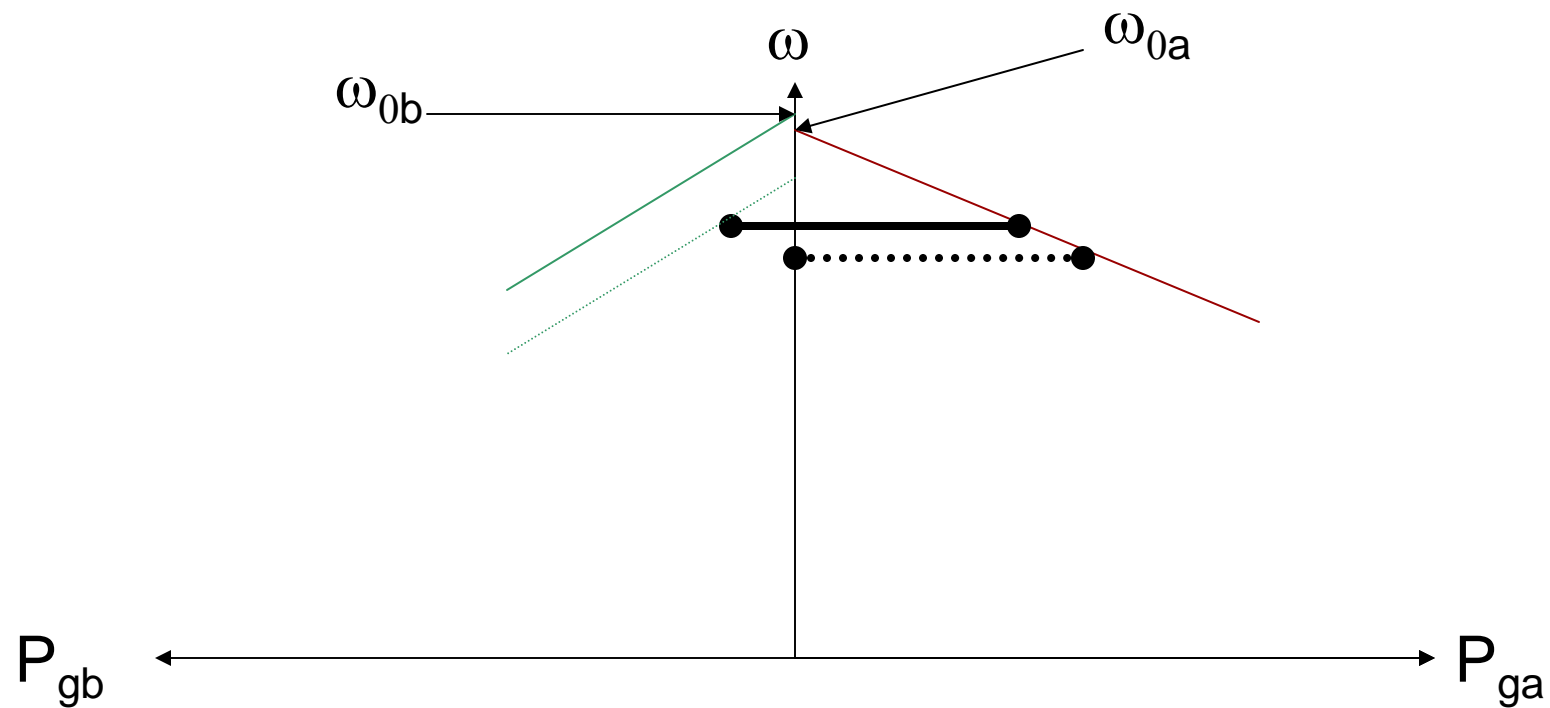
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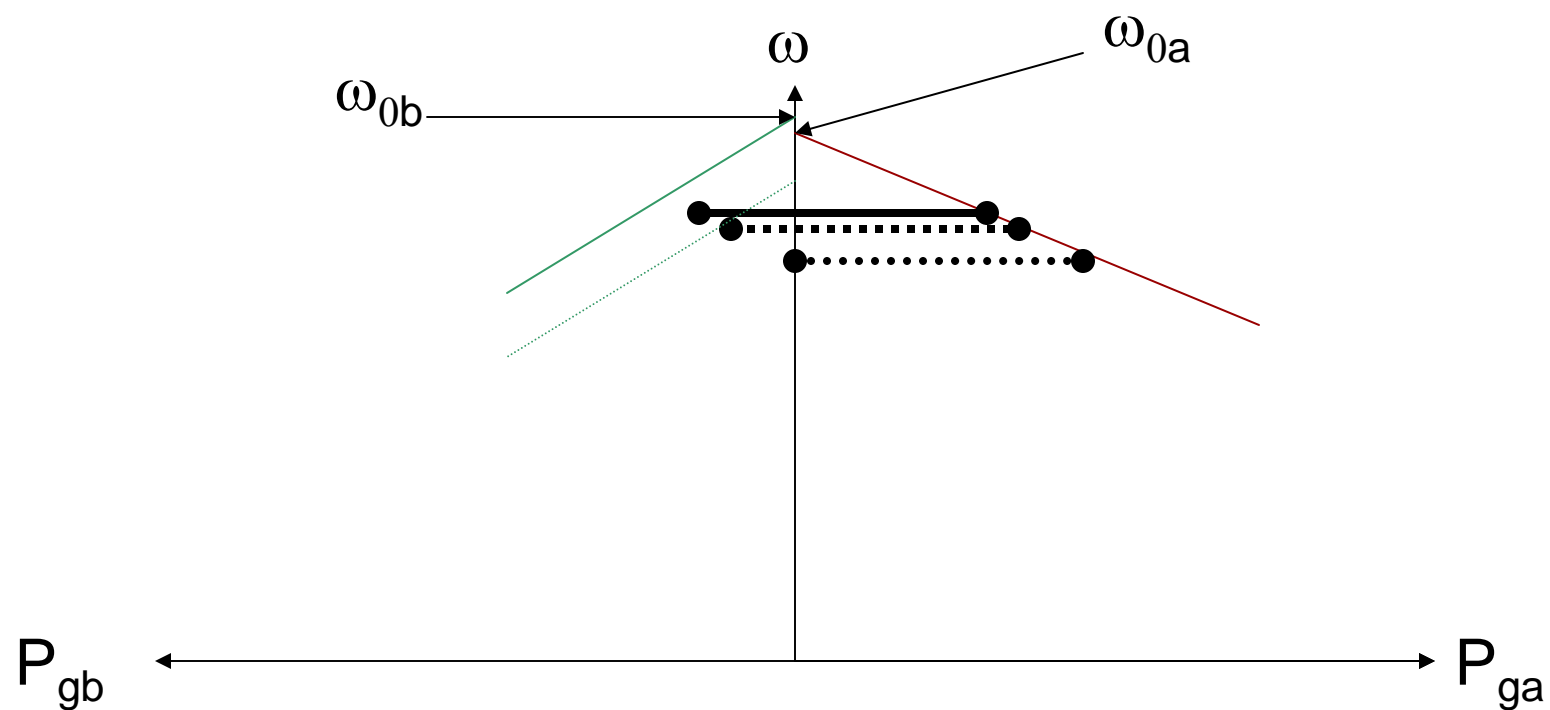
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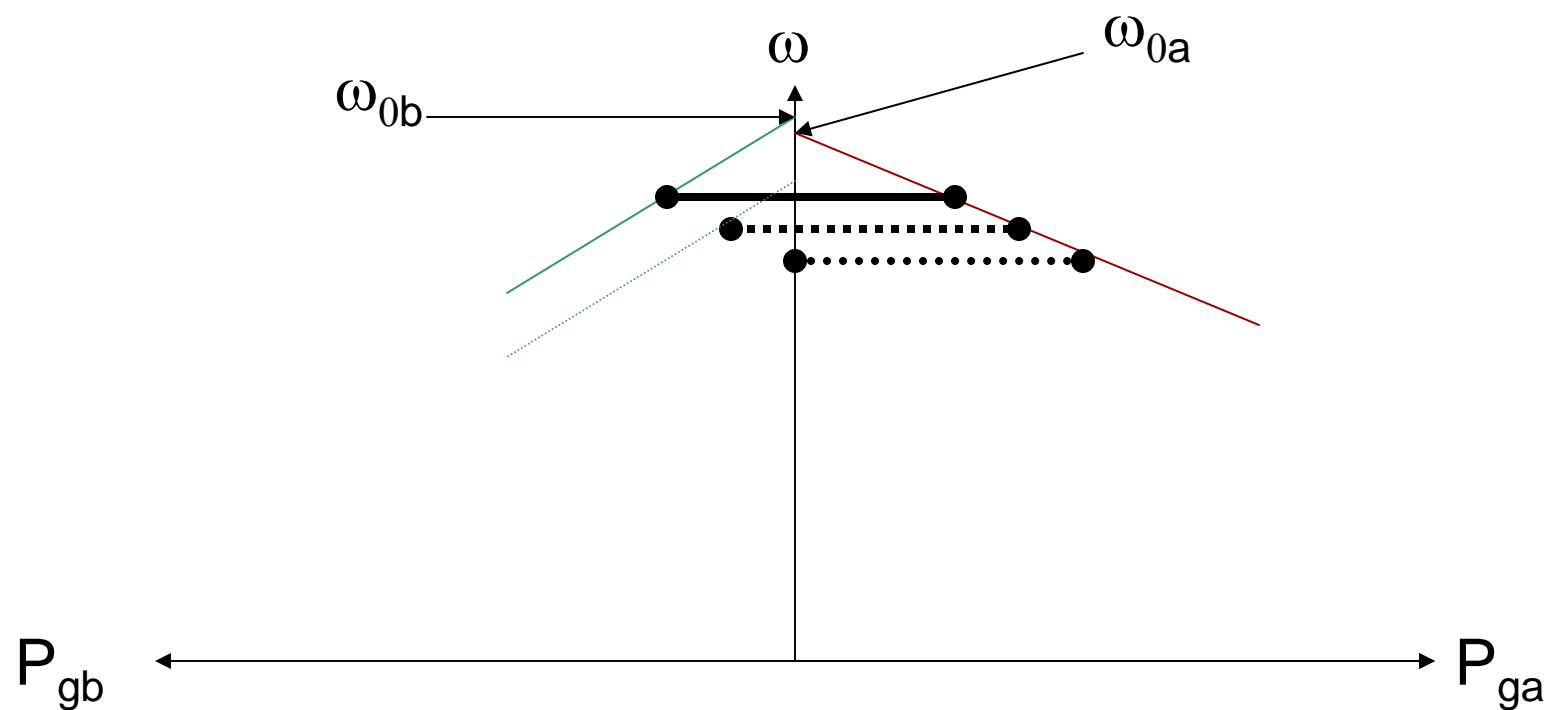
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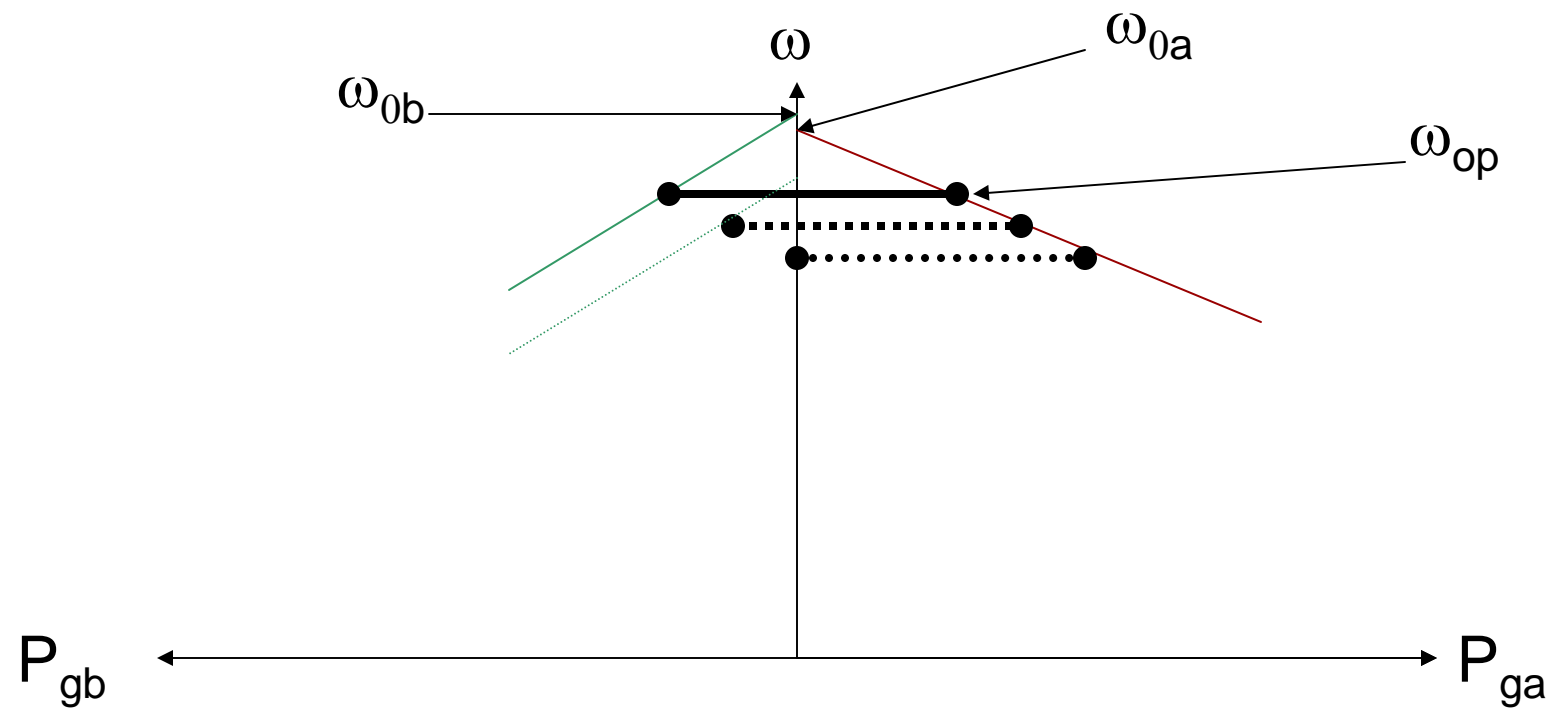
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Generator Interaction

- System frequency
 - Dependent on load
 - Affected by generator setpoints
 - Adjustable through 1 generator

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Questions?