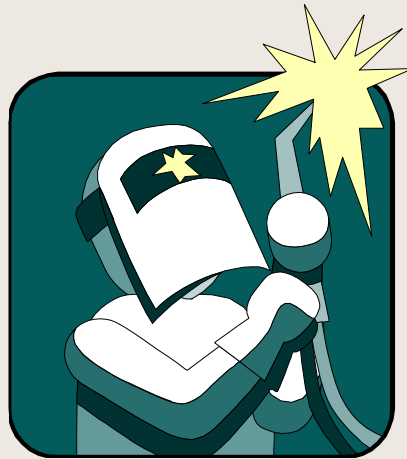


A spiral-bound notebook with a light beige, textured cover. The metal spiral binding is visible on the left side. The text is centered on the cover.

# Generators

What its all about

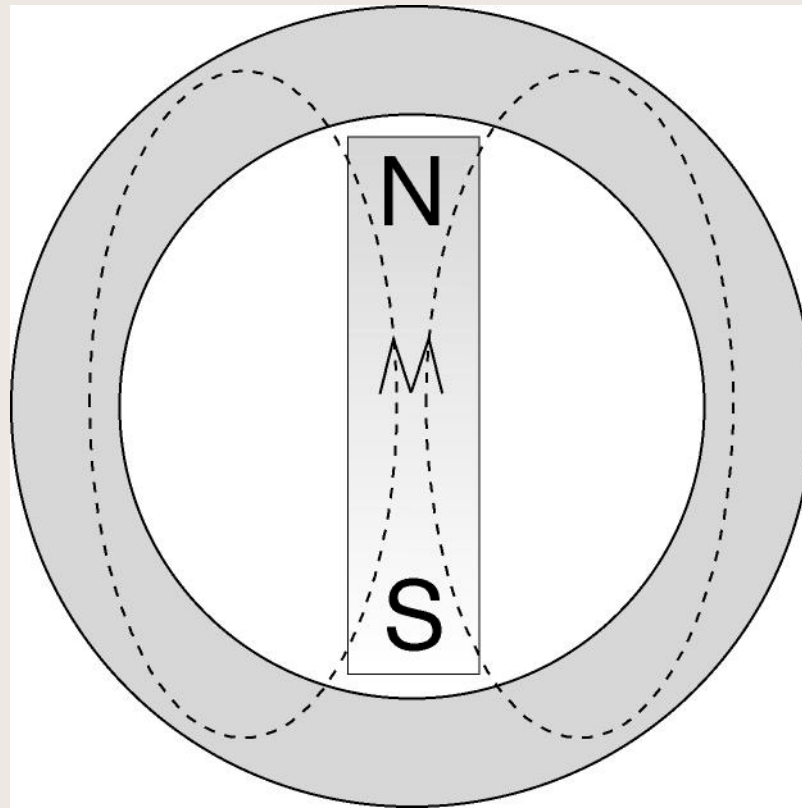
# How do we make a generator?



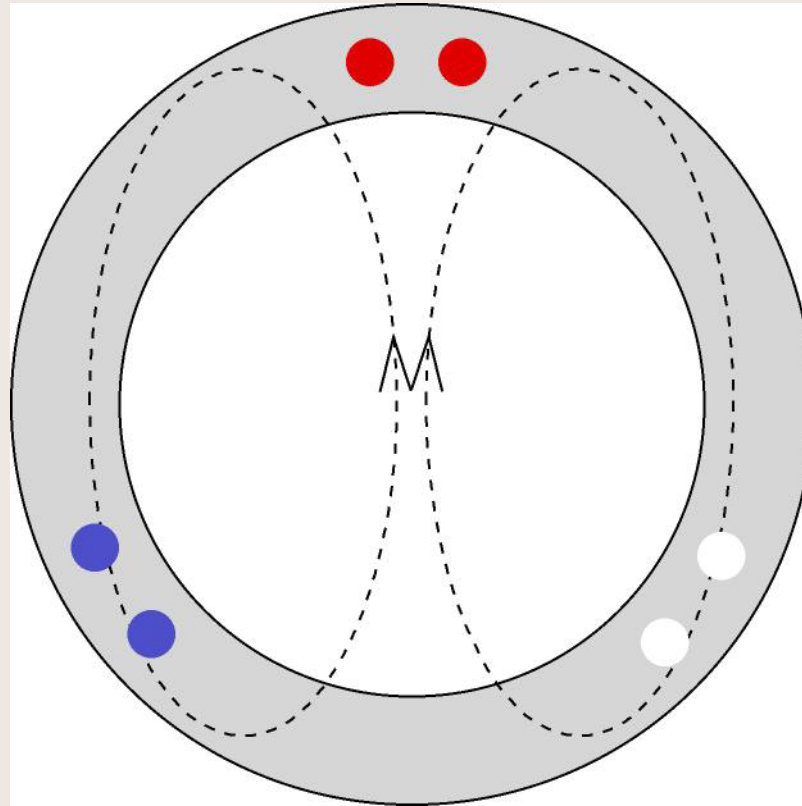
A spiral-bound notebook with a light beige, textured cover. The metal spiral binding is on the left side. The text "Synchronous Operation" is printed in a black serif font in the center of the cover.

# Synchronous Operation

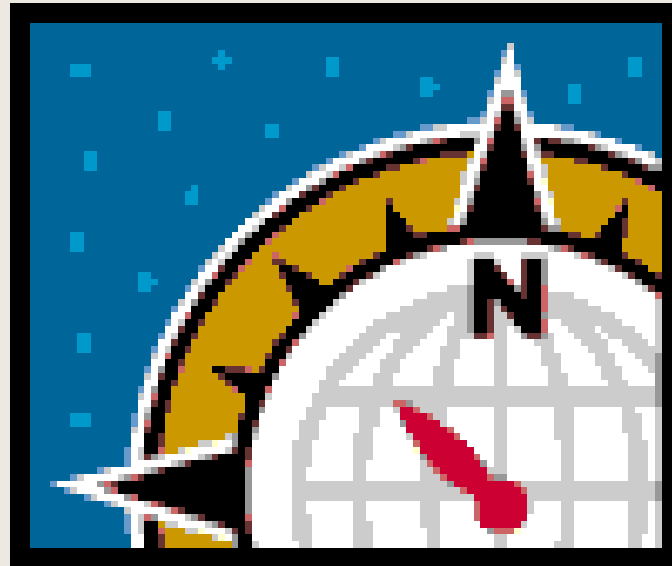
# Rotor Magnetic Field



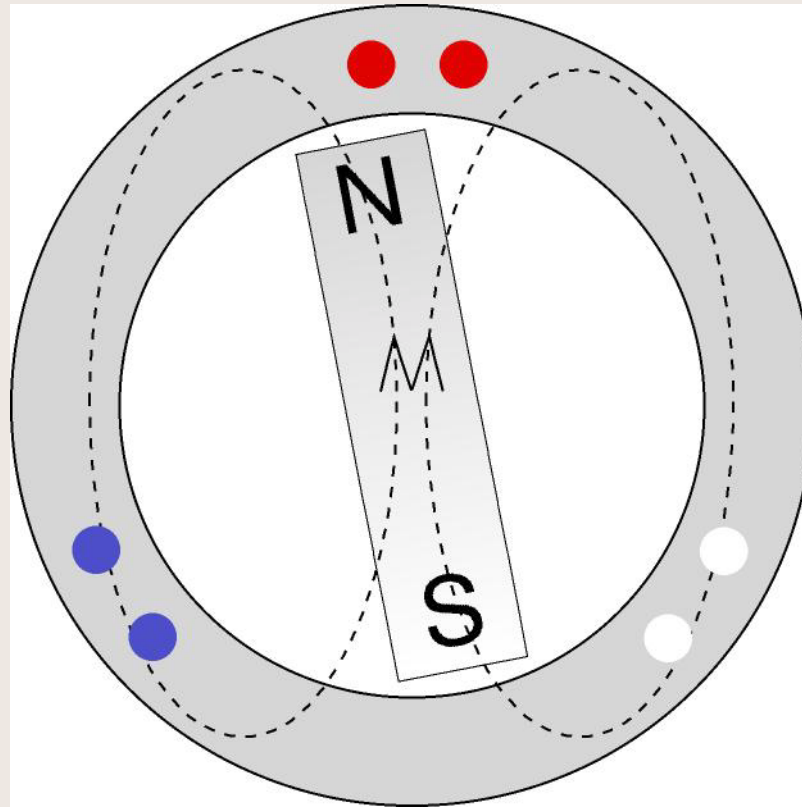
# Stator Magnetic Field



# Forces and Magnetic Fields



# Force Between Fields



# Motoring

- Generators & motors are the same thing
- Generators motor if they are synchronized and the governor is closed
- Power flows in from the grid

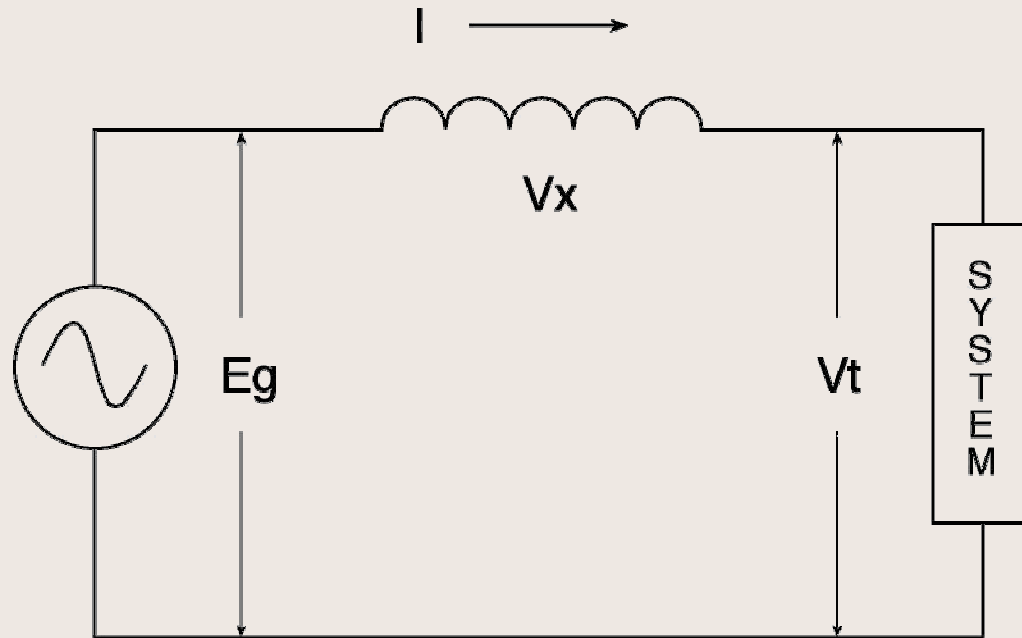


# Limits

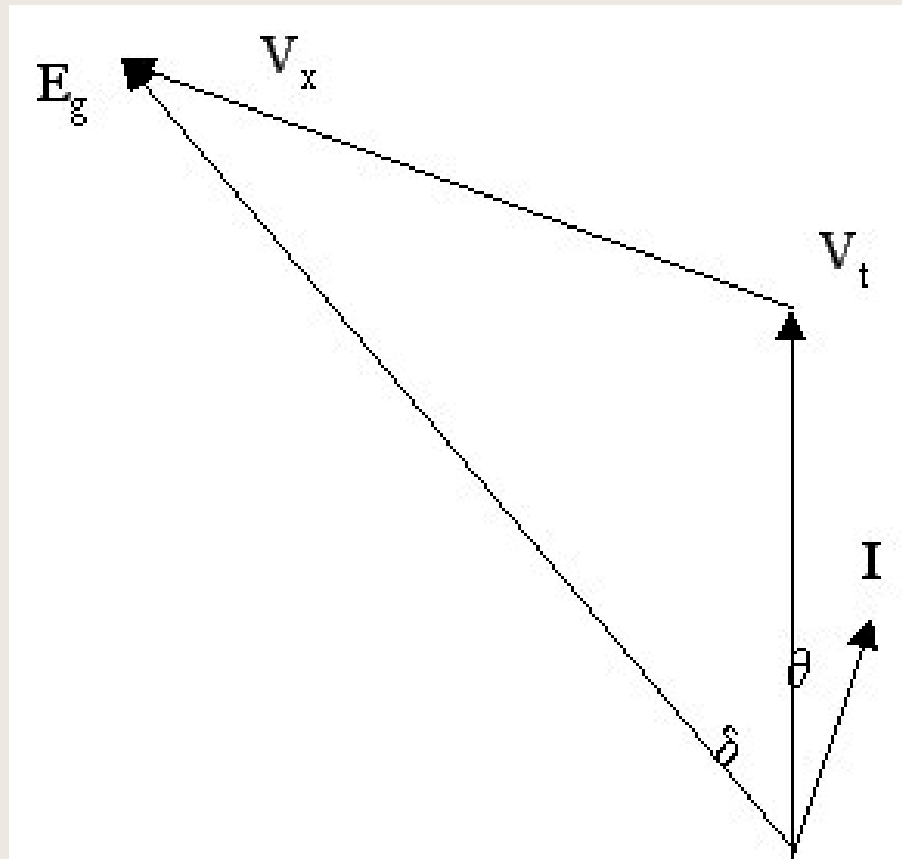
- Under steady state conditions the load angle must be less than  $90^\circ$
- Exceeding  $90^\circ$  leads to pole slipping
  - Tremendous current and torque pulsations
  - Can lead to catastrophic failures



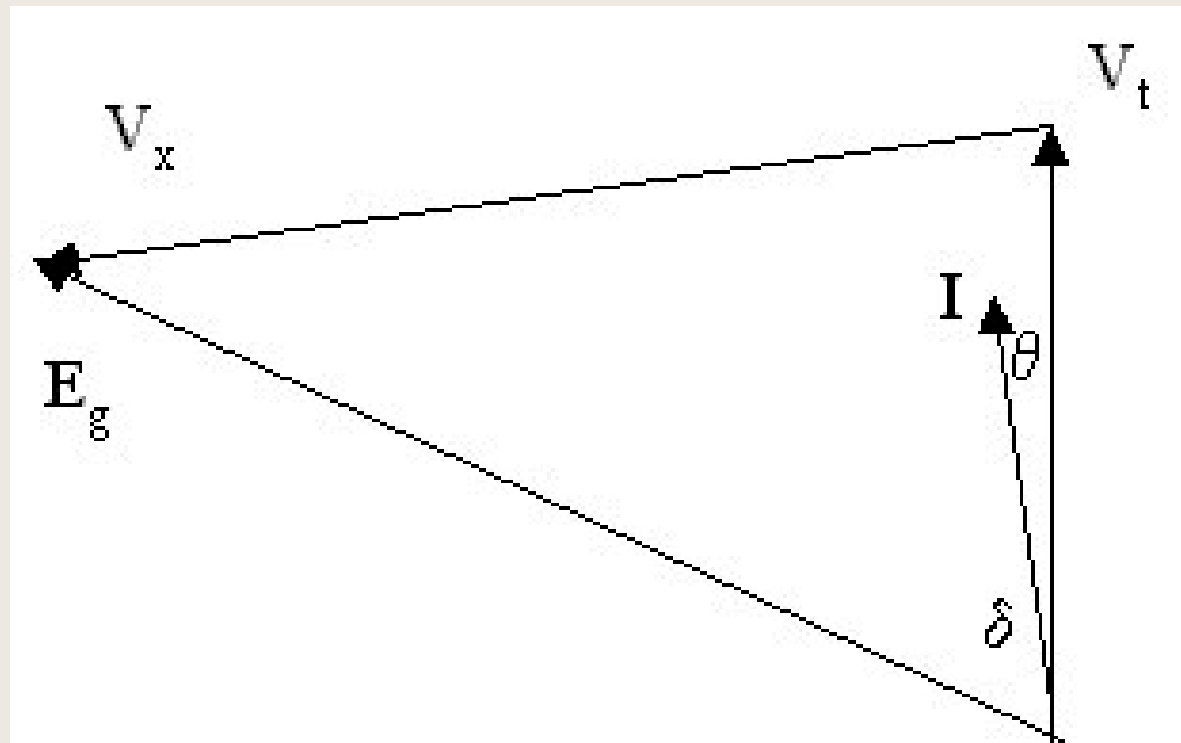
# Generator Simplified Equivalent Circuit

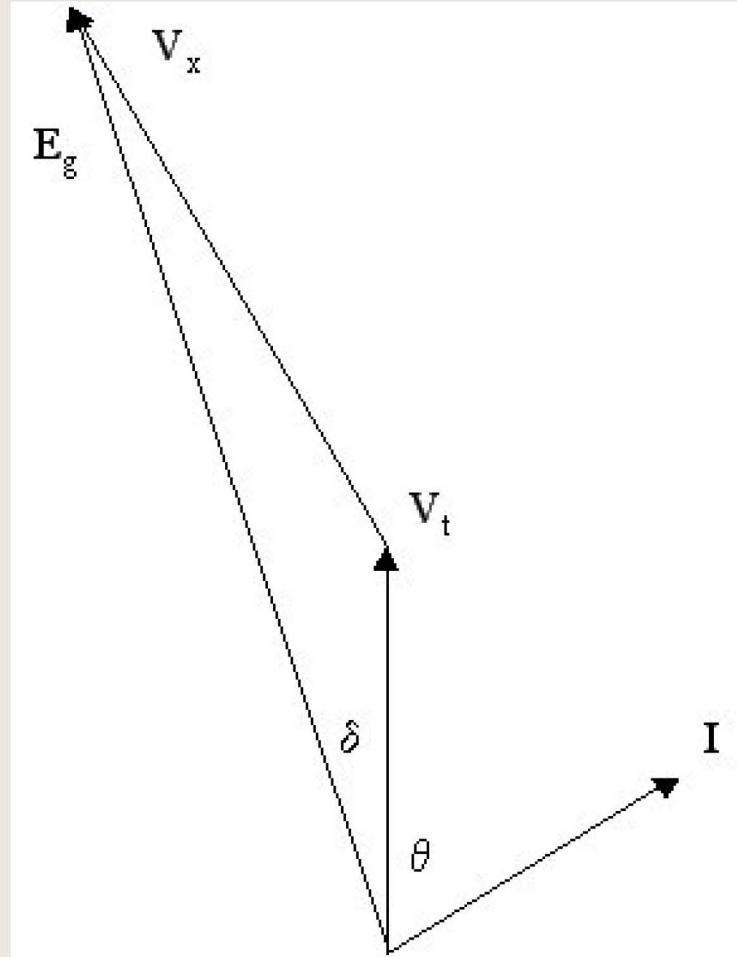


# Phasor Diagram



# Increasing Steam Flow

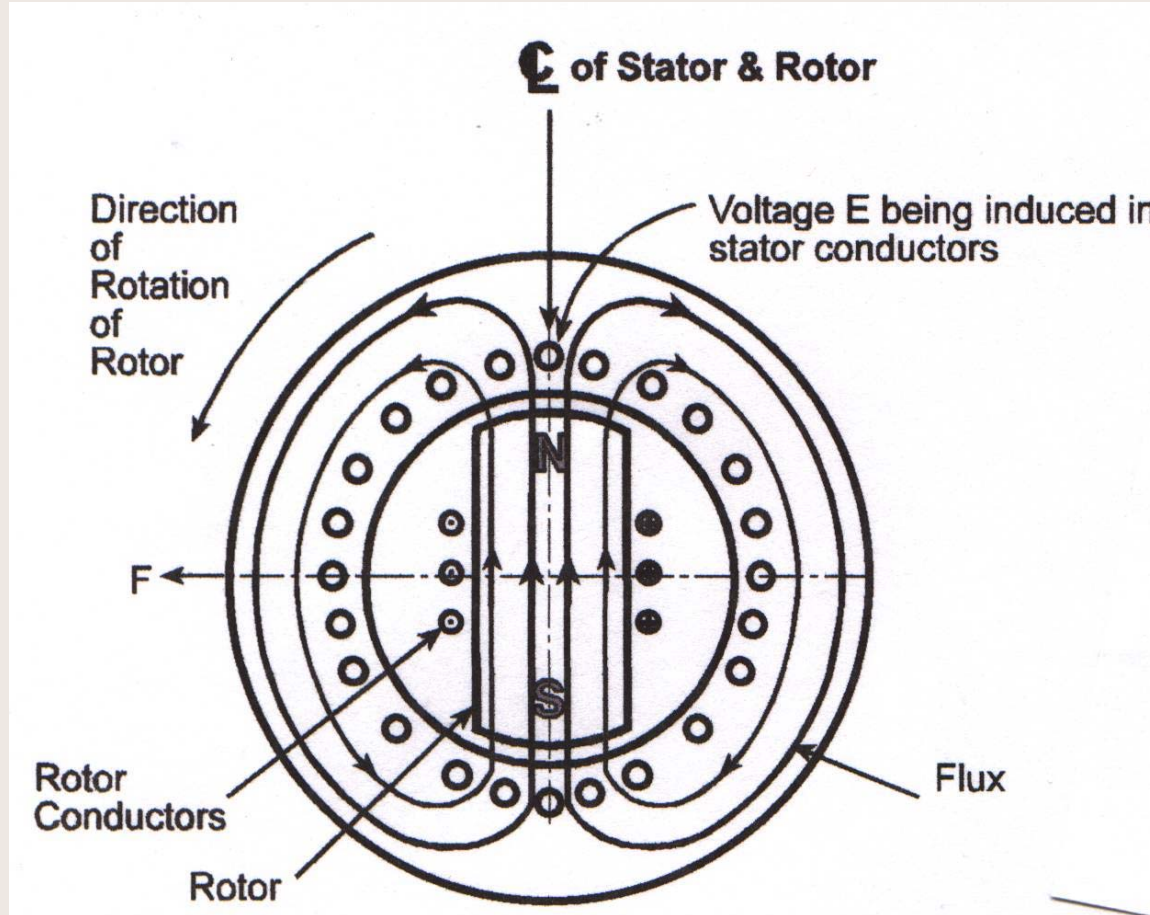




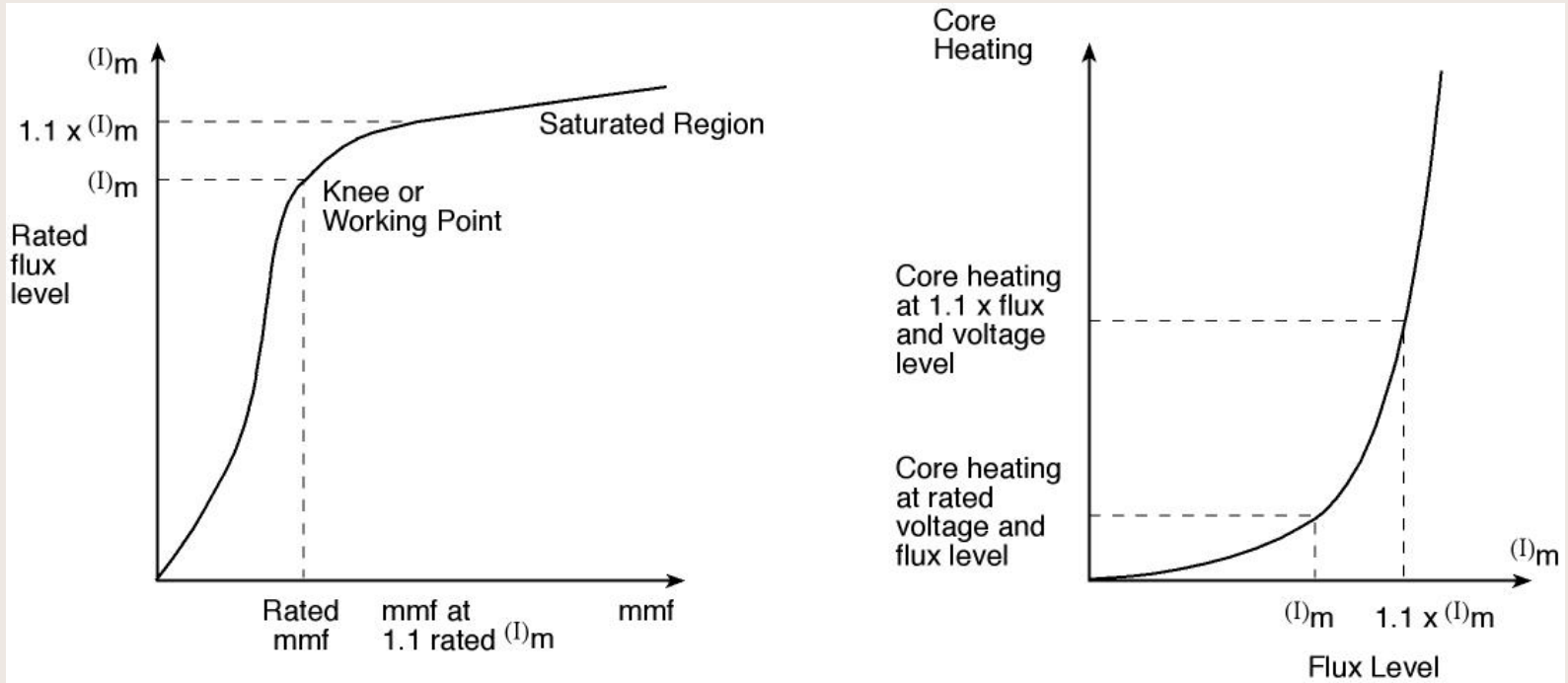
# Synchronizing

- Machine is run up to speed
  - 1800 rpm (4 pole machine)
- Field is applied
- Machine is adjust so  $E_g = V_t$  in magnitude and phase
- Breaker is closed to connect generator to the system

# Generator Prior to Synchronization



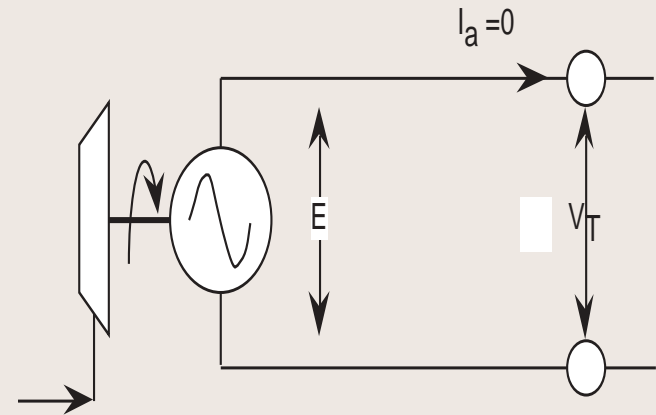
# Magnetic Core Heating

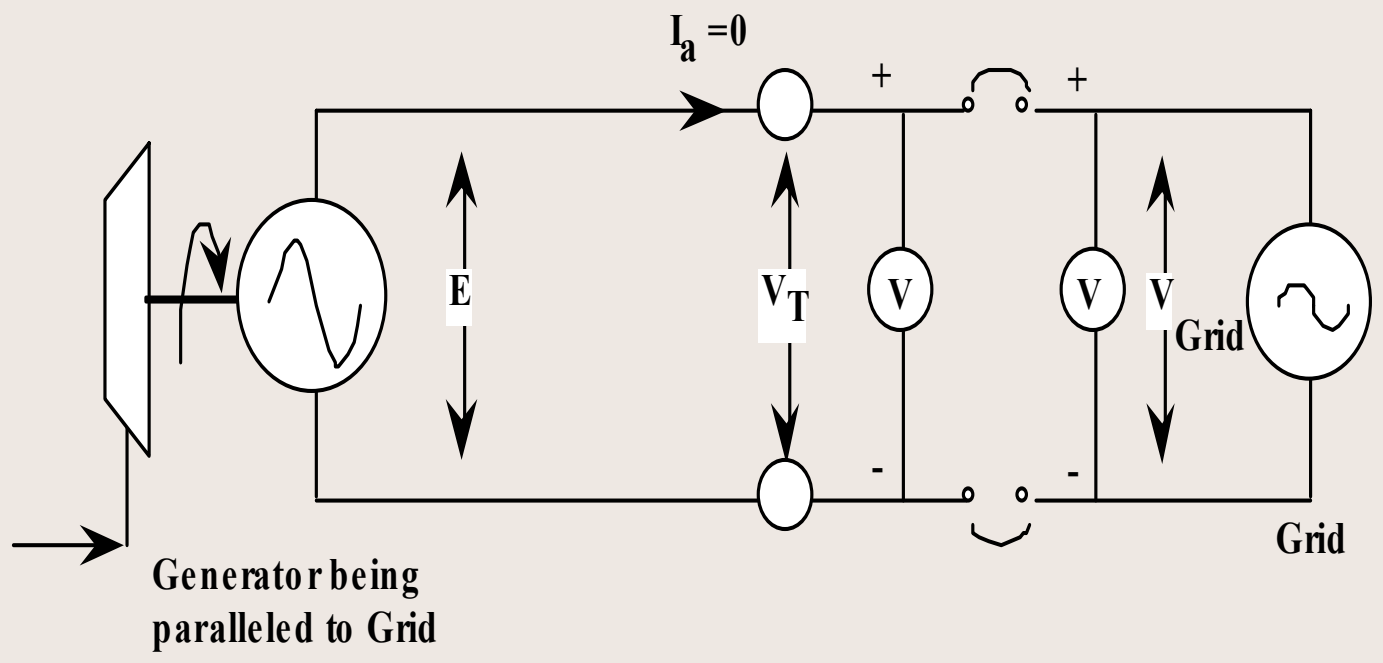




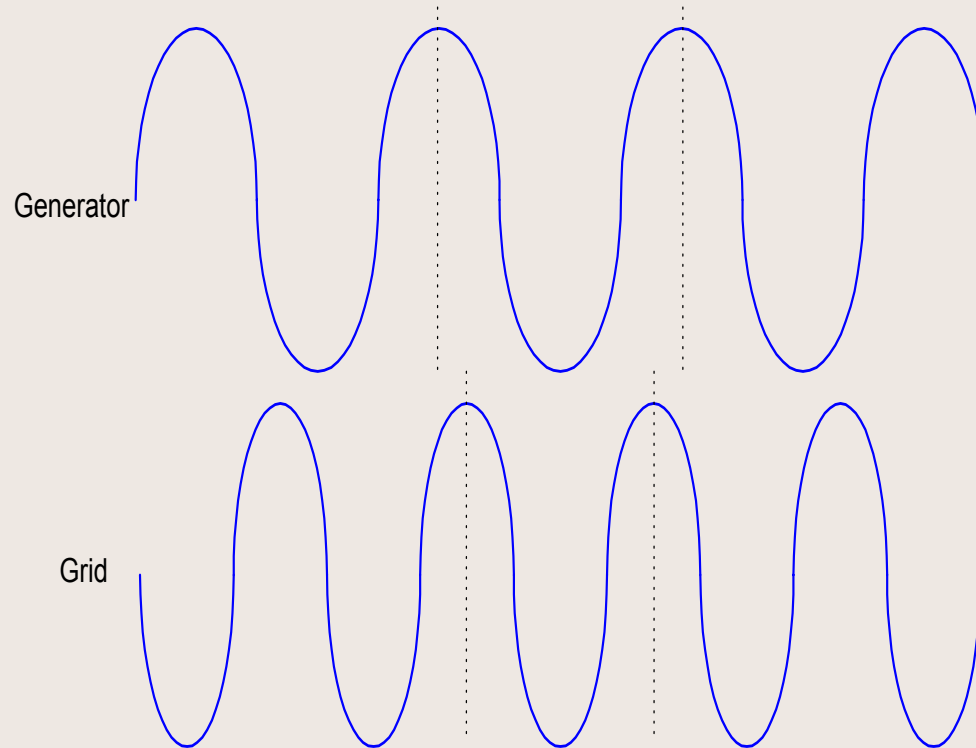
# Conditions for Synchronization

- Phase sequence
- Voltage magnitude
- Frequency
- Phase angle

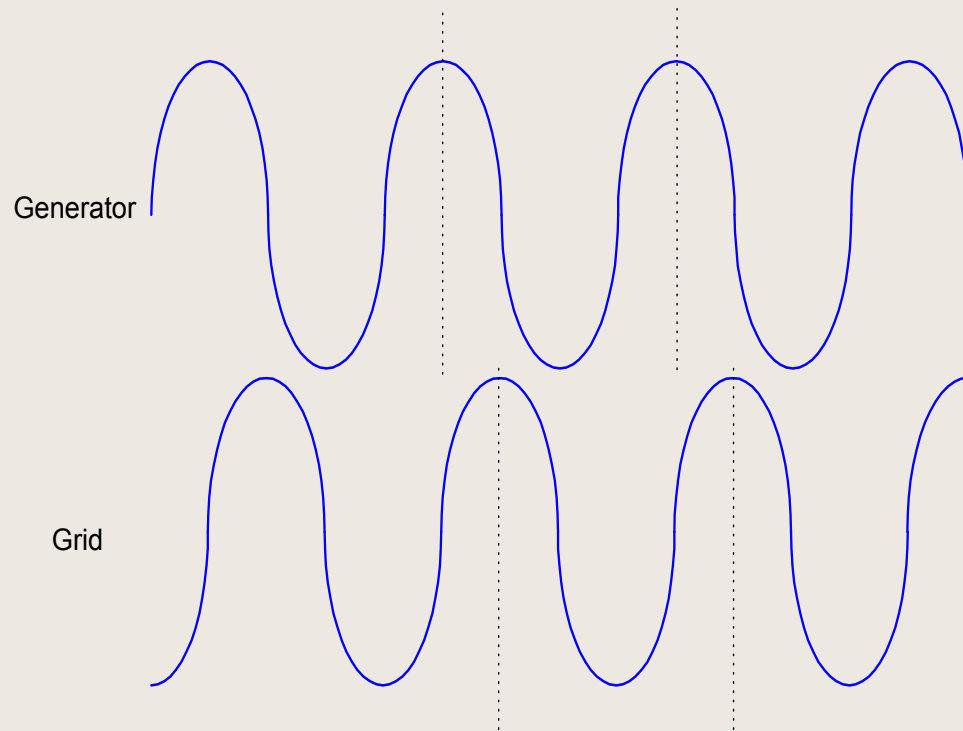




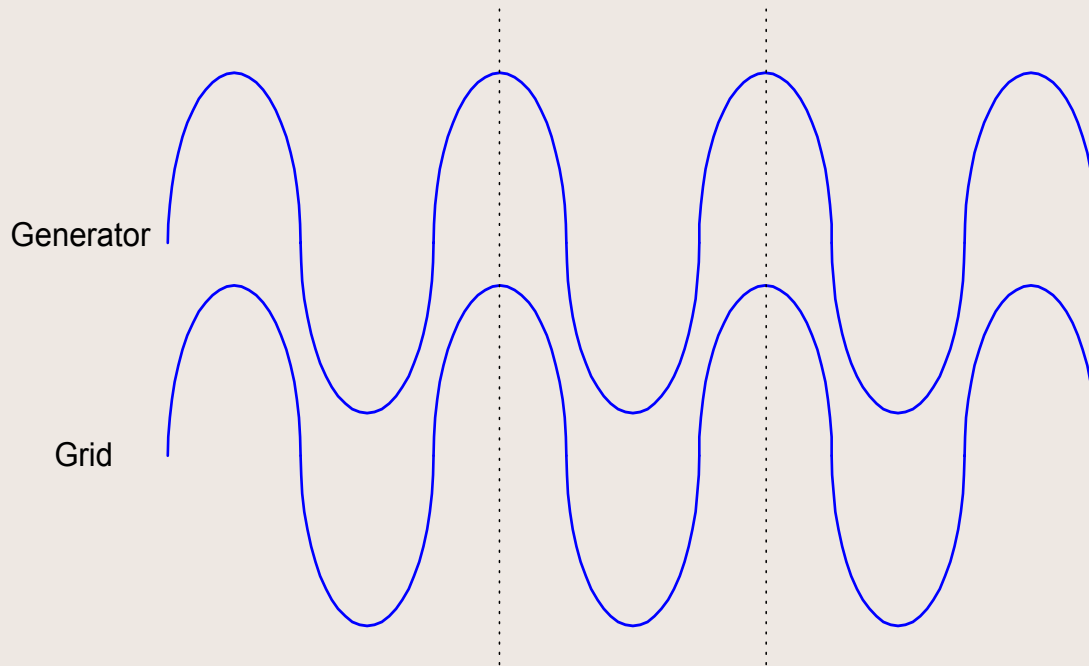
# Machine slower than system



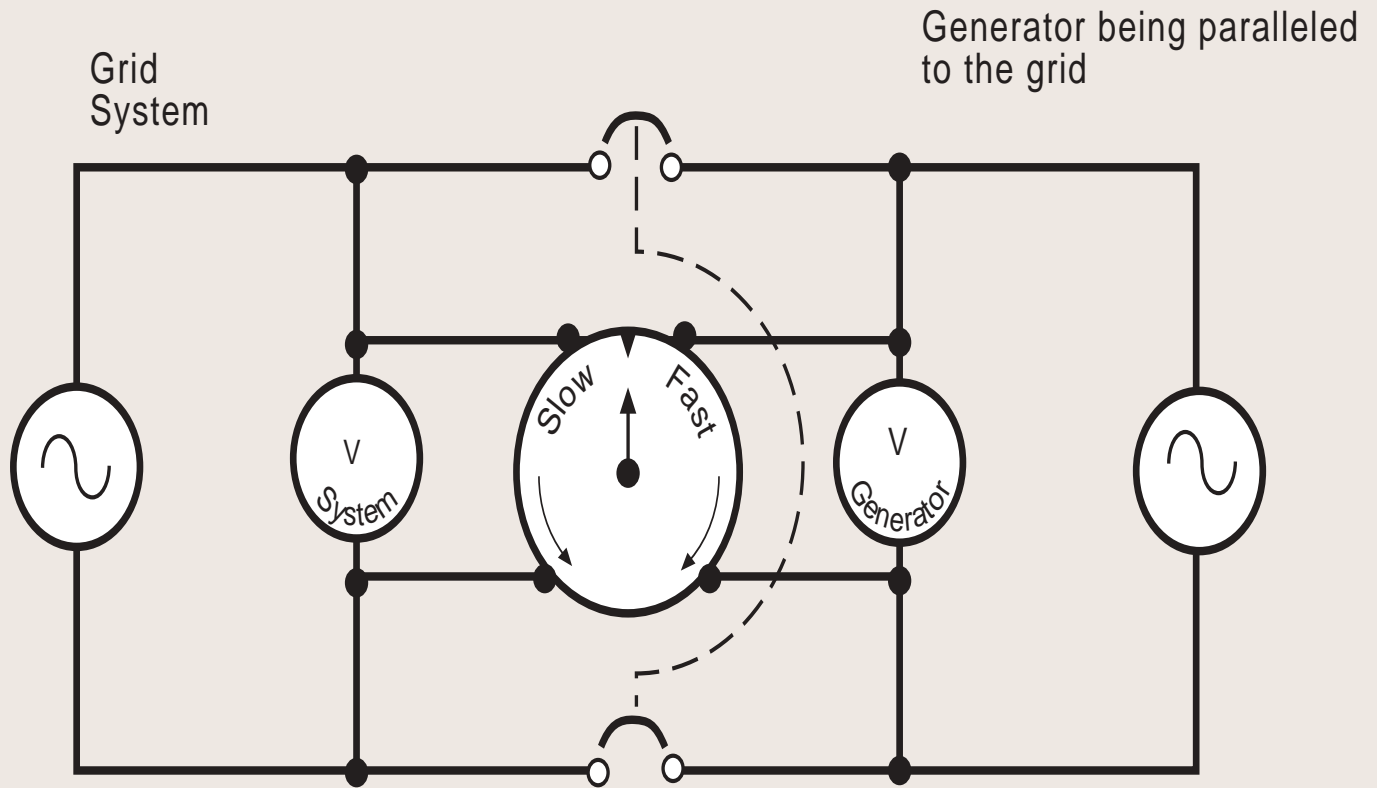
# Phase Angle



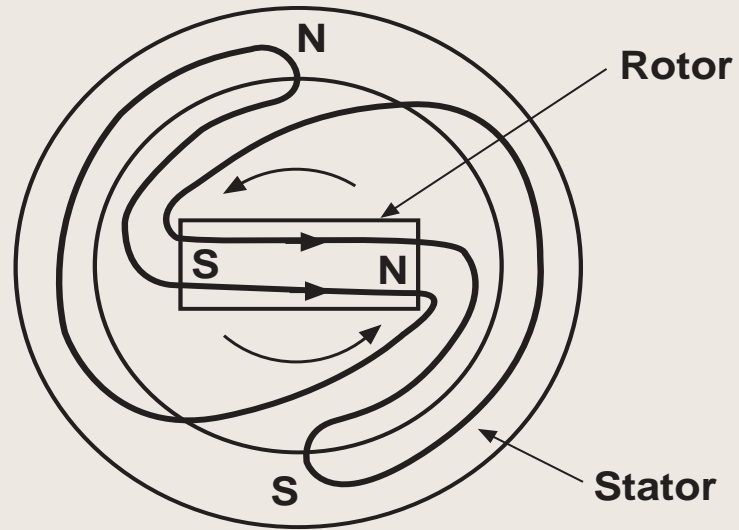
# Properly Synchronized



# Synchronizing Equipment



# Armature Reaction



# Closing onto a dead bus

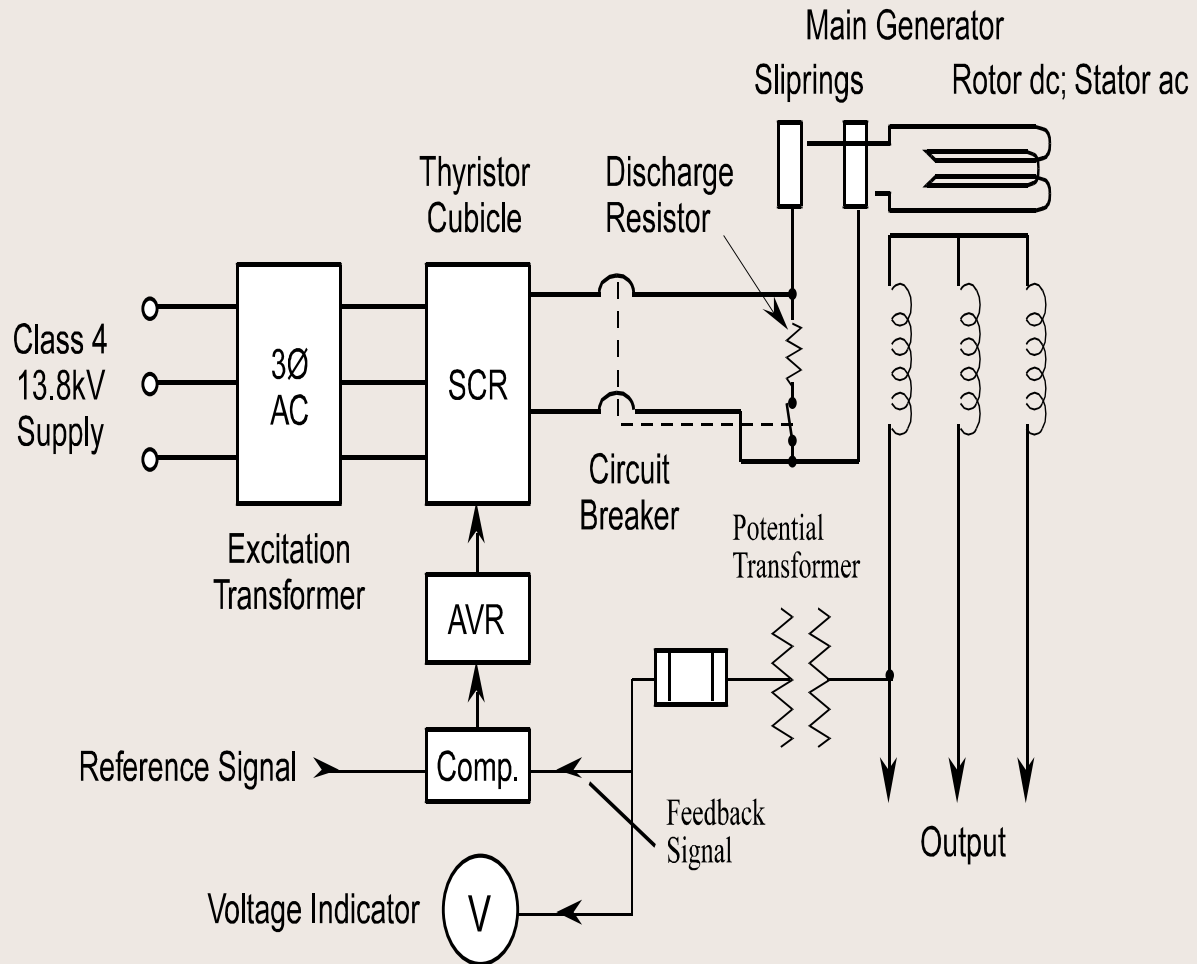
- Leading PF
  - AVR will reduce excitation
- Lagging PF
  - Terminal voltage will drop AVR increases excitation
- Faulted Bus
  - High currents flow
- No load
  - Nothing happens



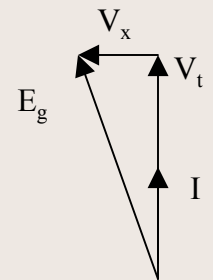
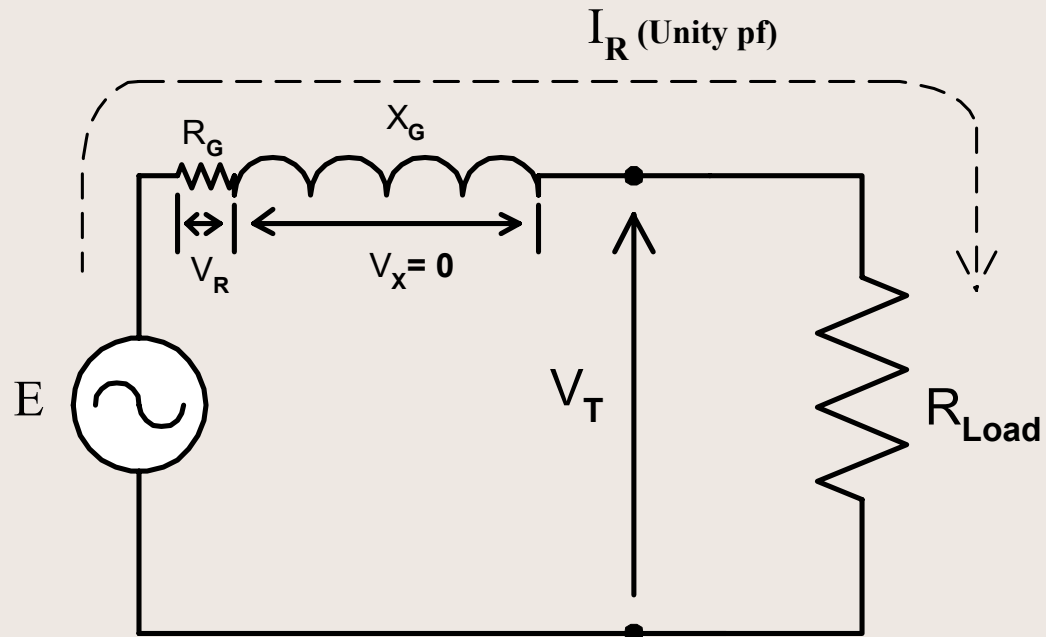
# Finite or Infinite

- Operation of the generator is apparently different
- Changes in steam valve position have no effect on speed (infinite)
- Changes in excitation only affect voltages locally
- Generator  $>5\%$  gives finite characteristics

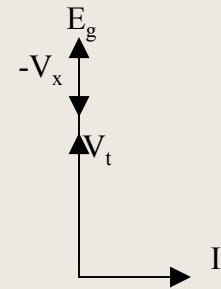
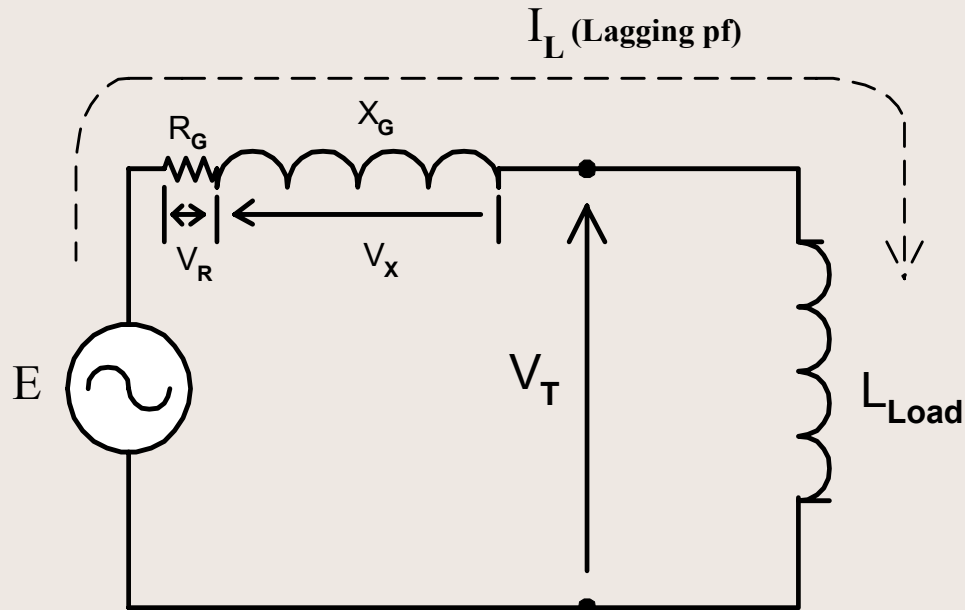
# AVR



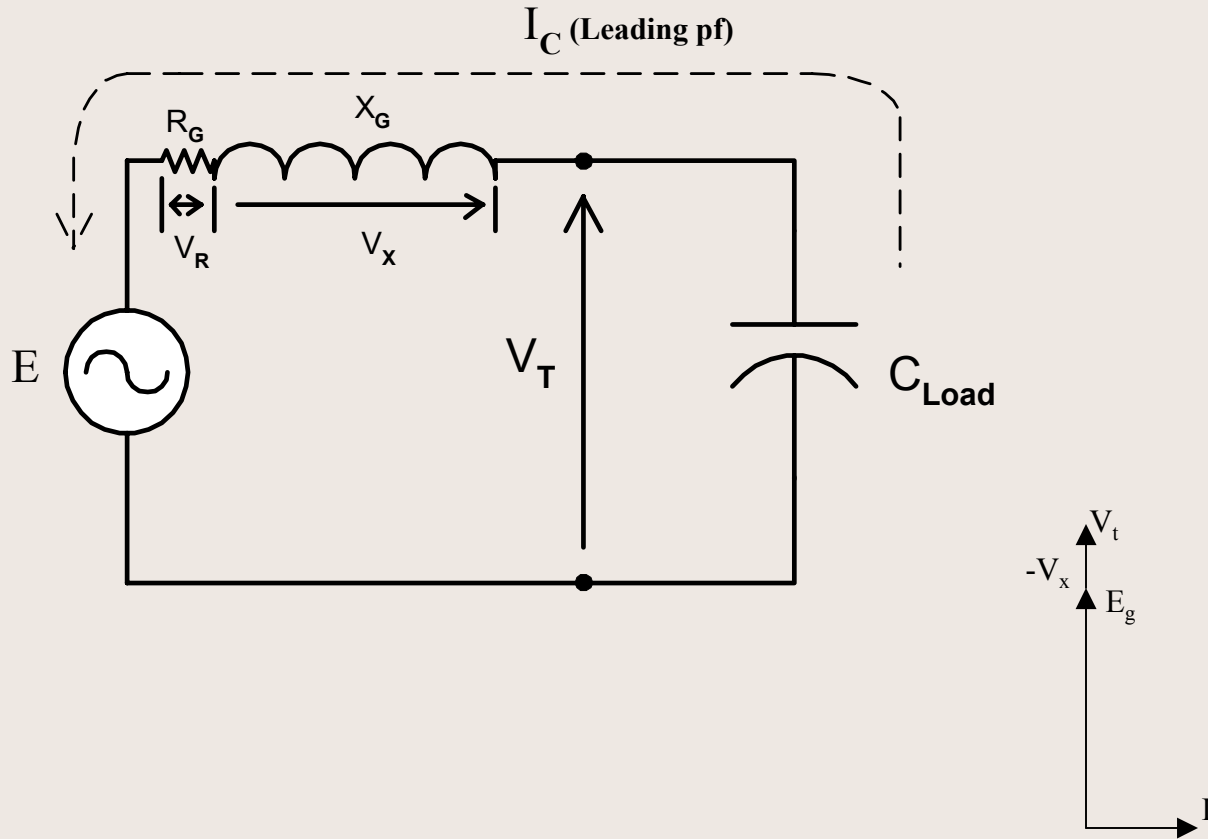
# Resistive Load



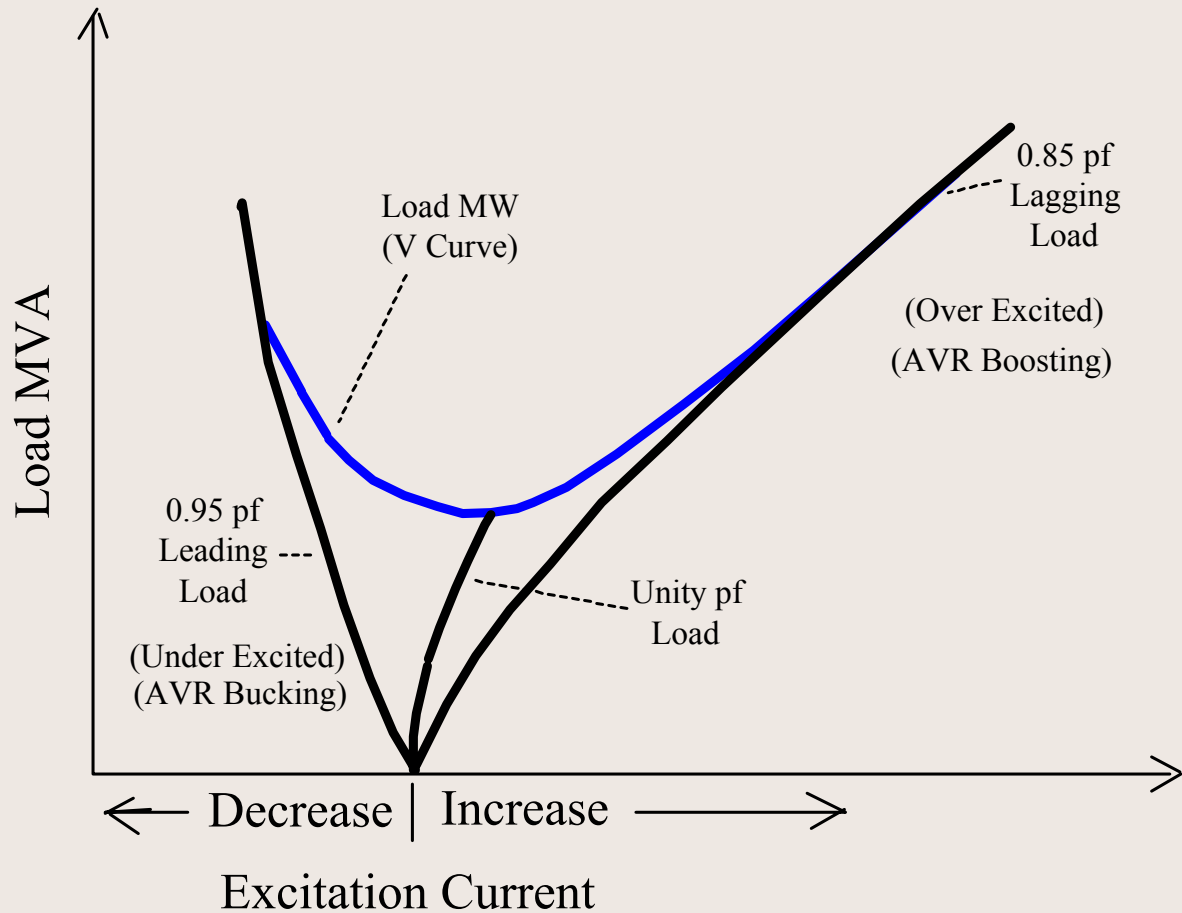
# Lagging Load



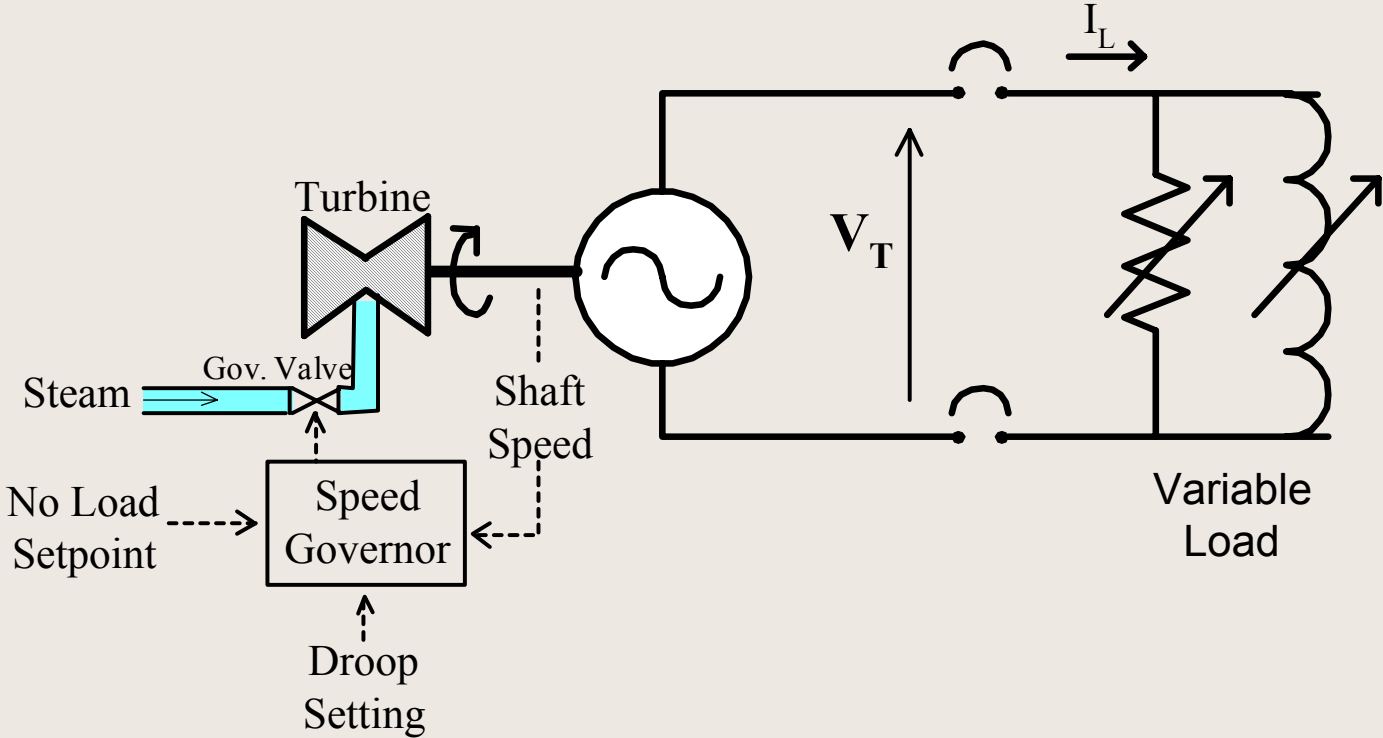
# Capacitive Load



# V-curves



# Governor Control



# Speed Droop

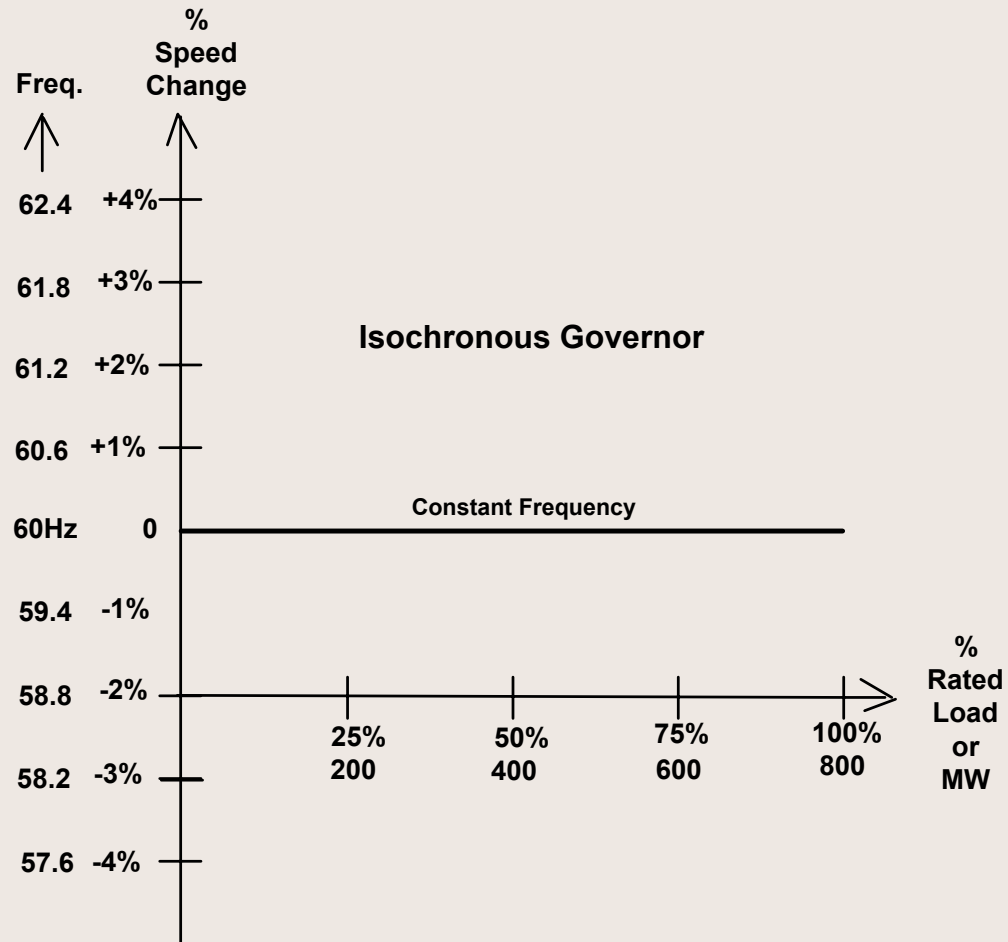
- Electrical word for proportional control

$$\text{Droop} = \frac{\text{Speed Drop NL to FL}}{\text{Rated Speed}} \times 100\%$$

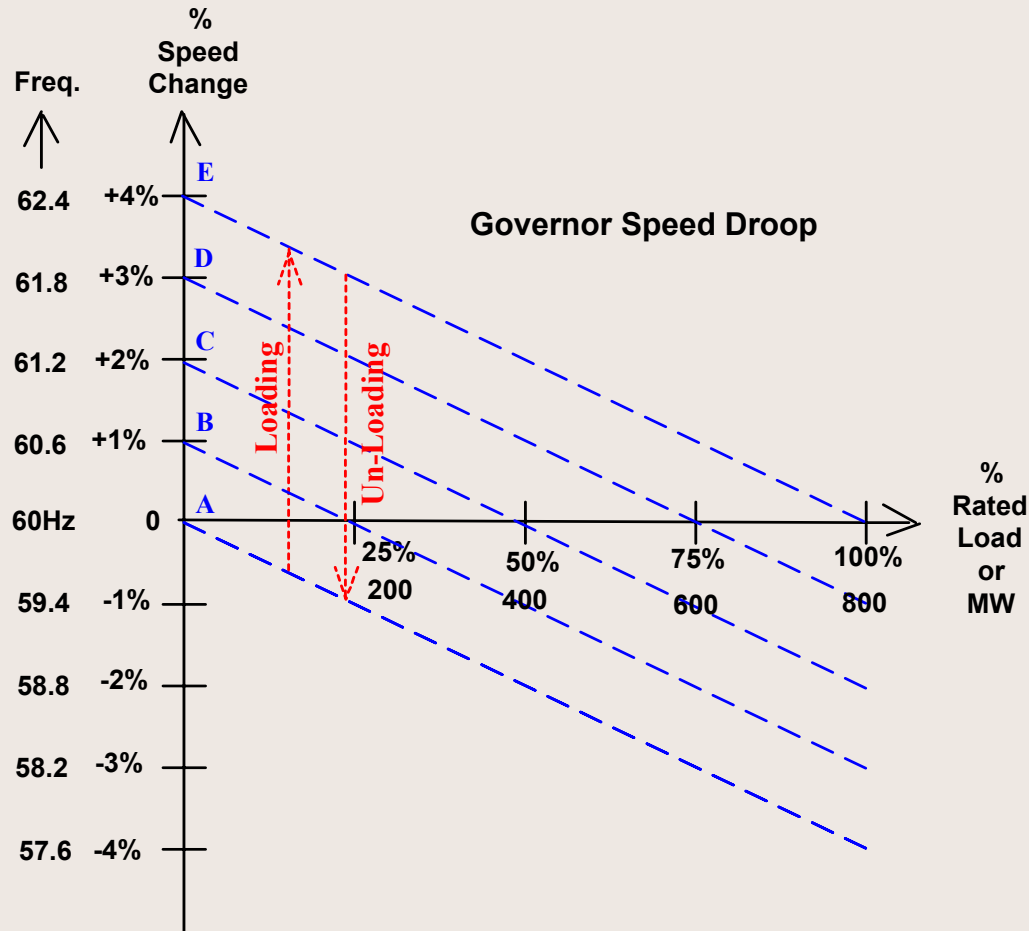
- Isochronous - proportional + integral



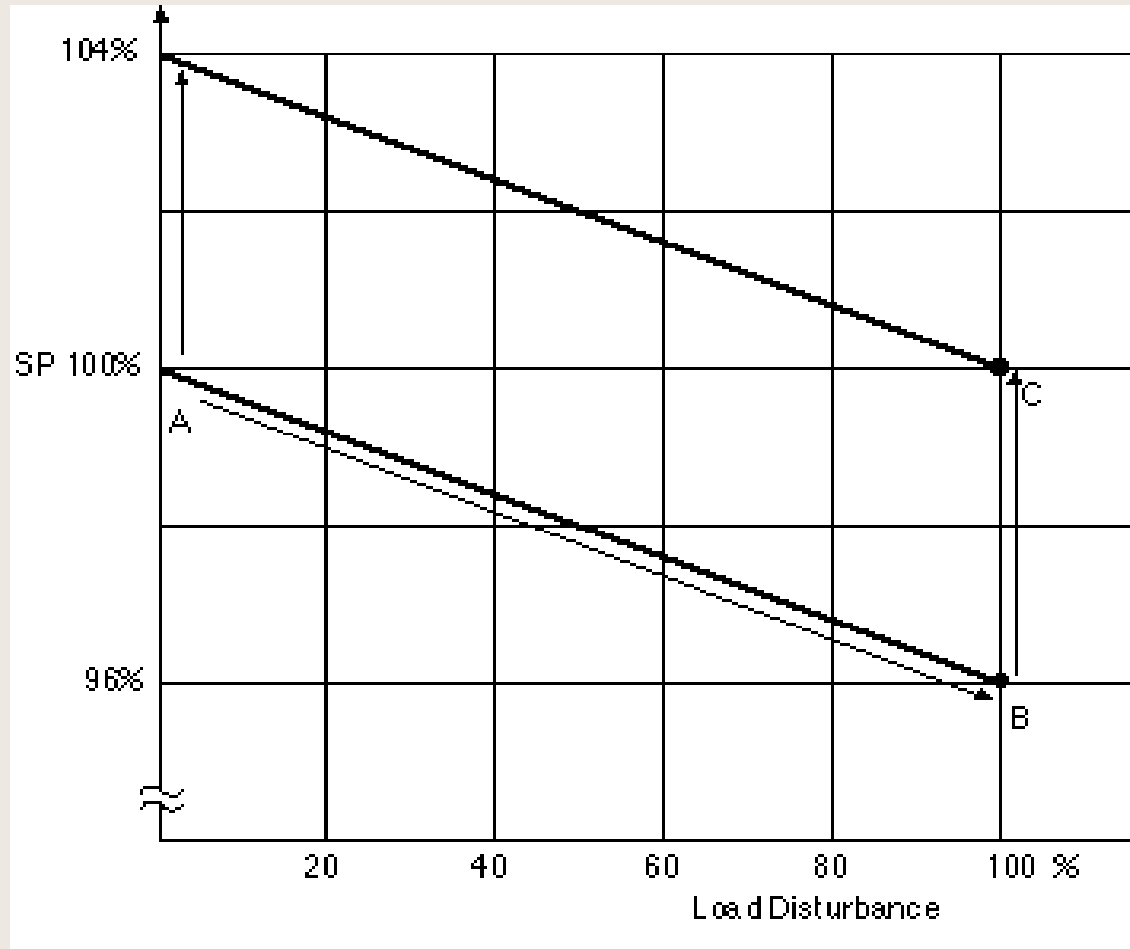
# Isochronous



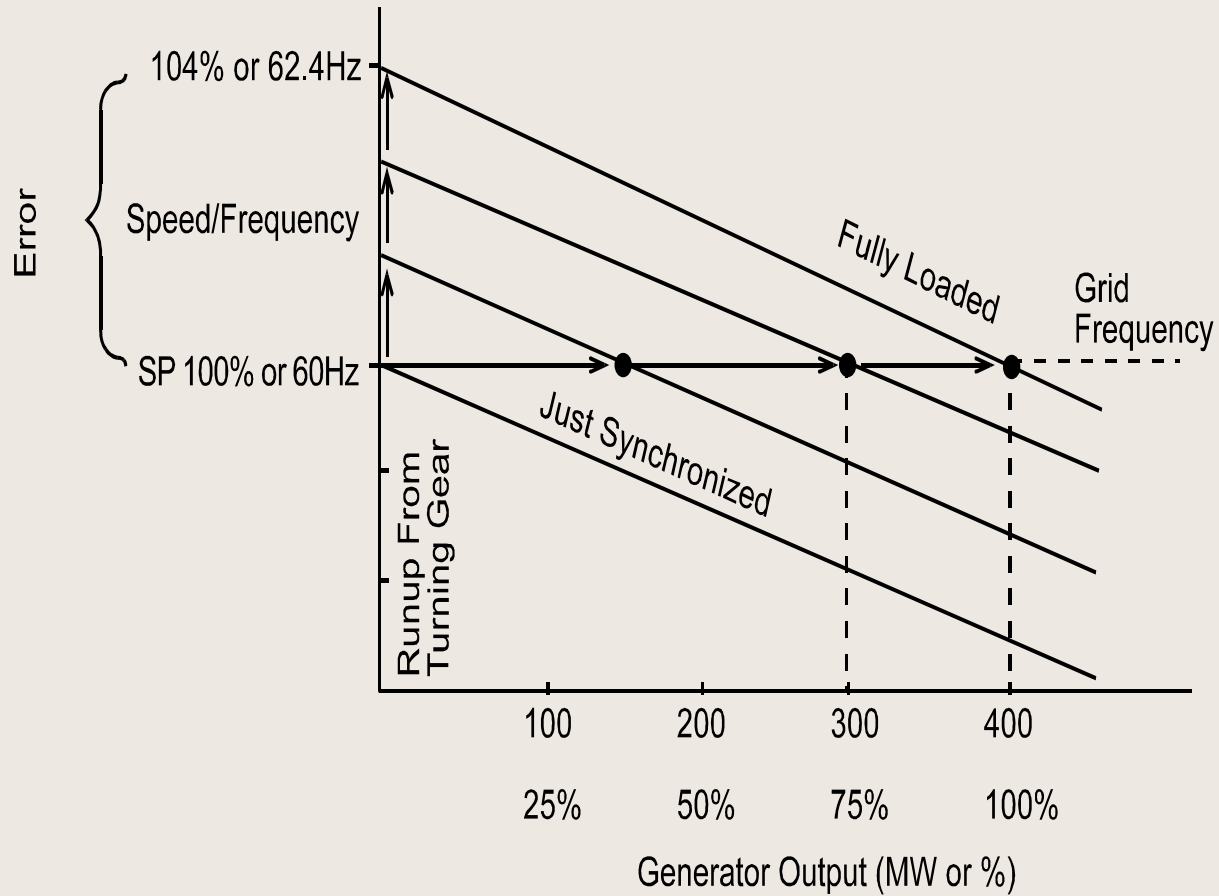
# 4% Droop



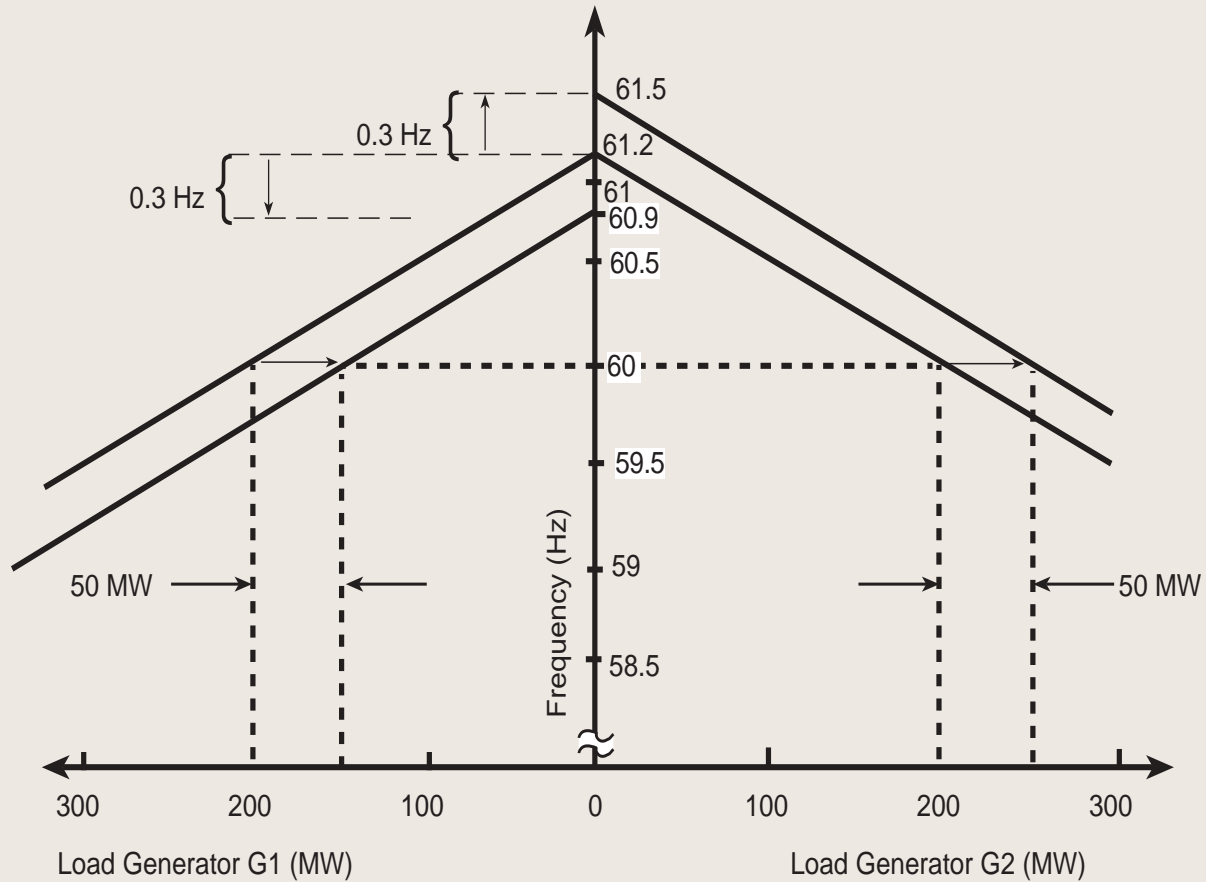
# Effect of Adding Load

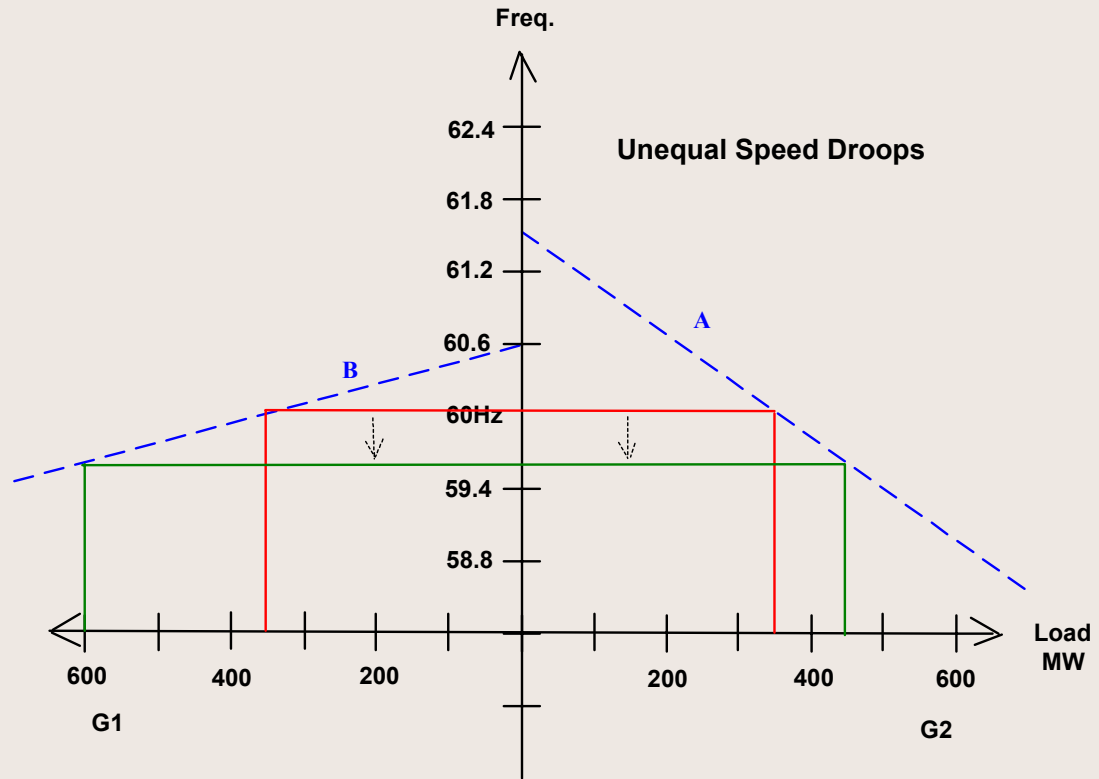


# Generator Synchronized

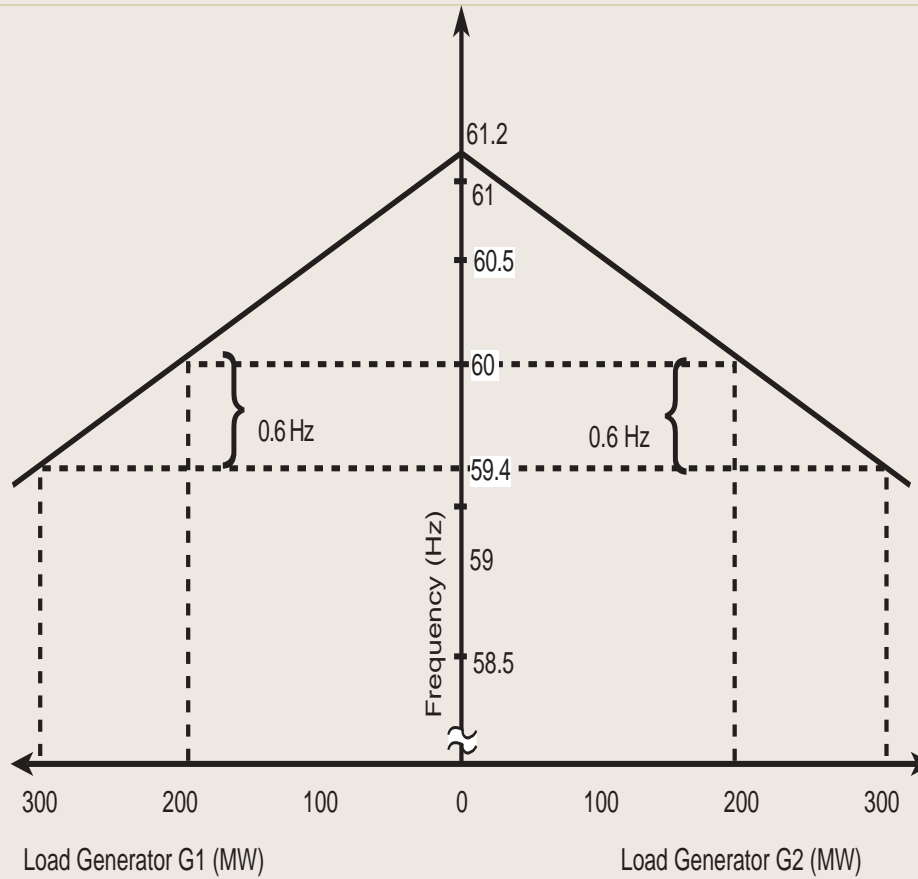


# Increasing Load

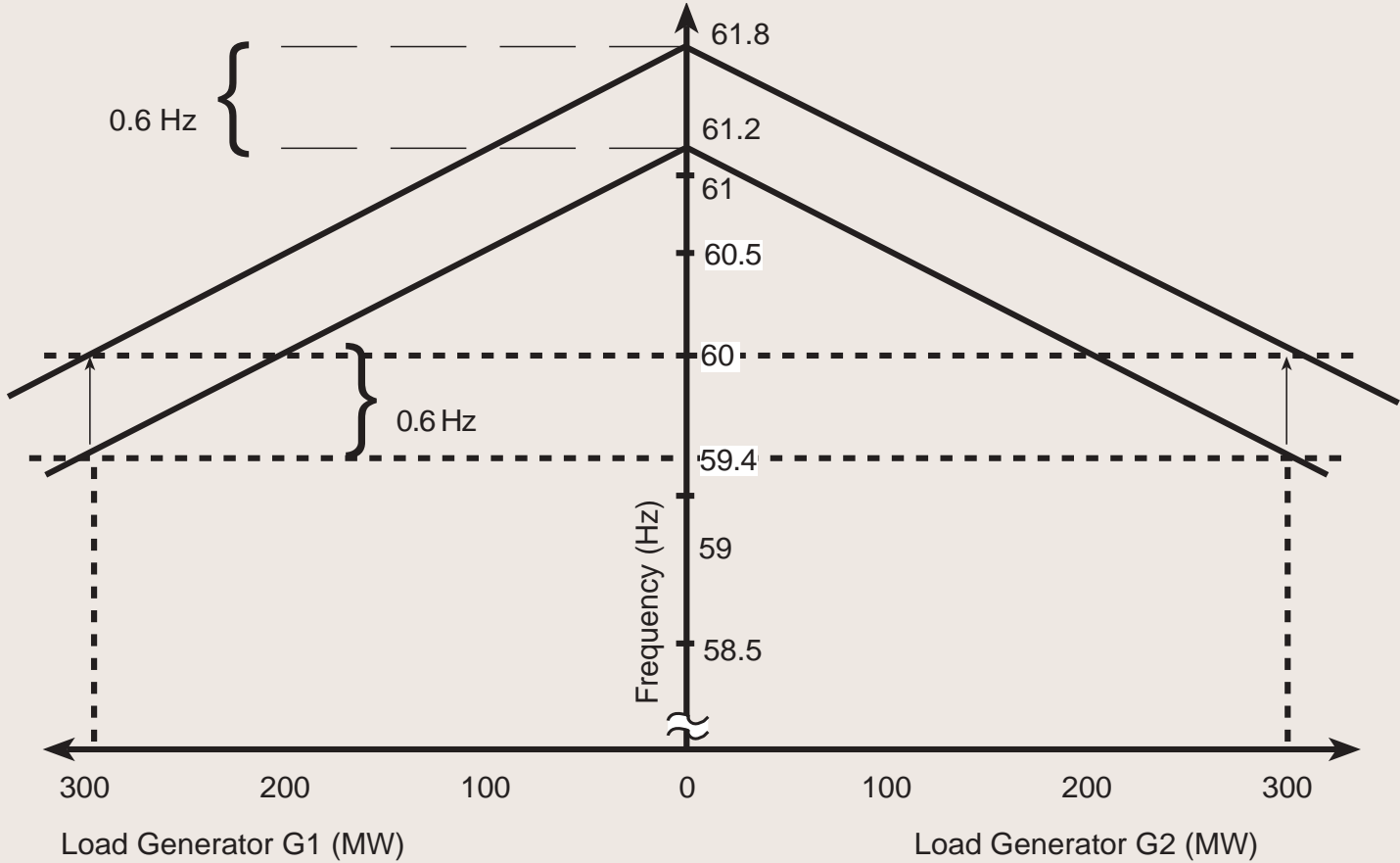




# Finite Bus

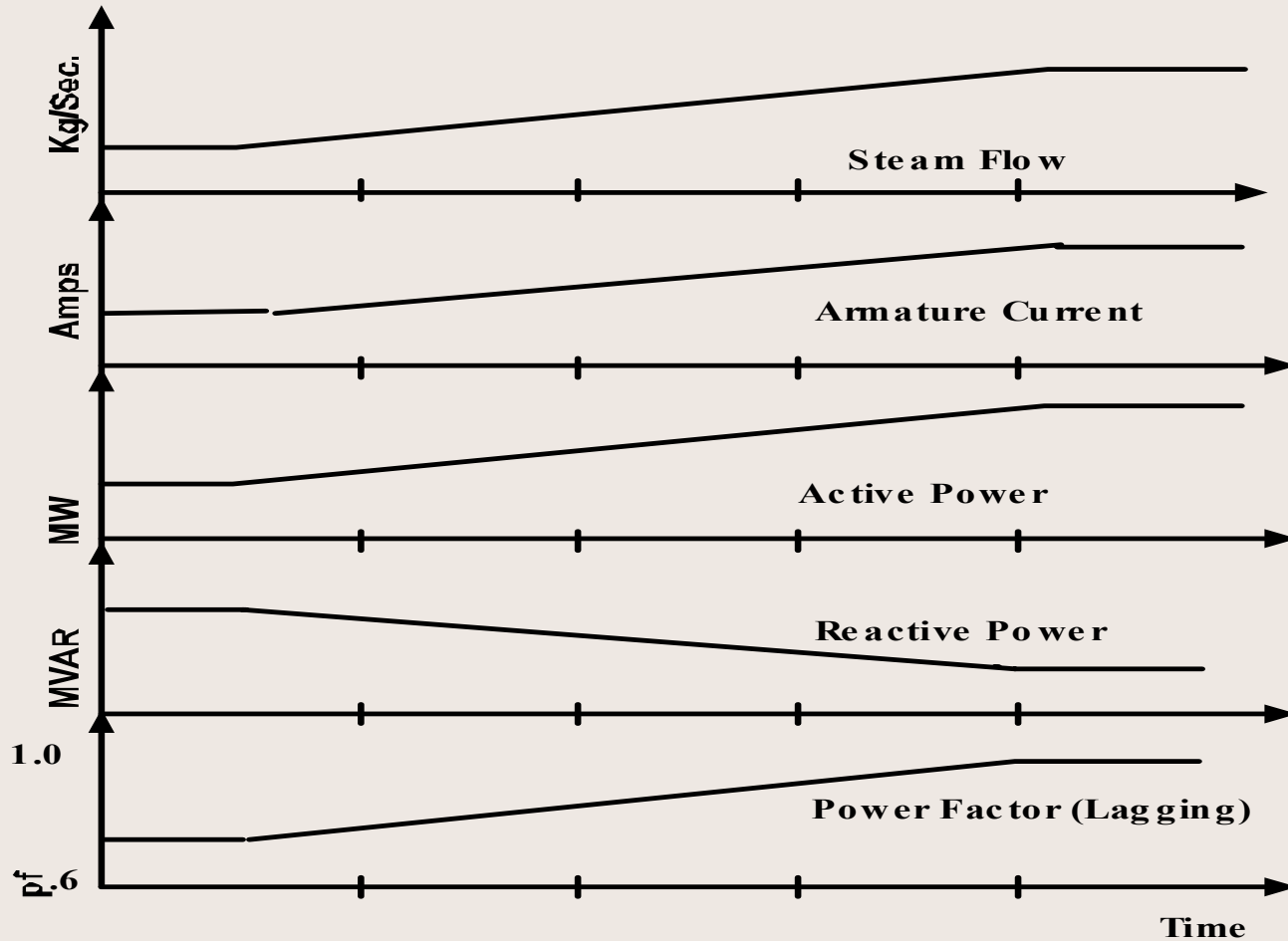


# Frequency Restoration

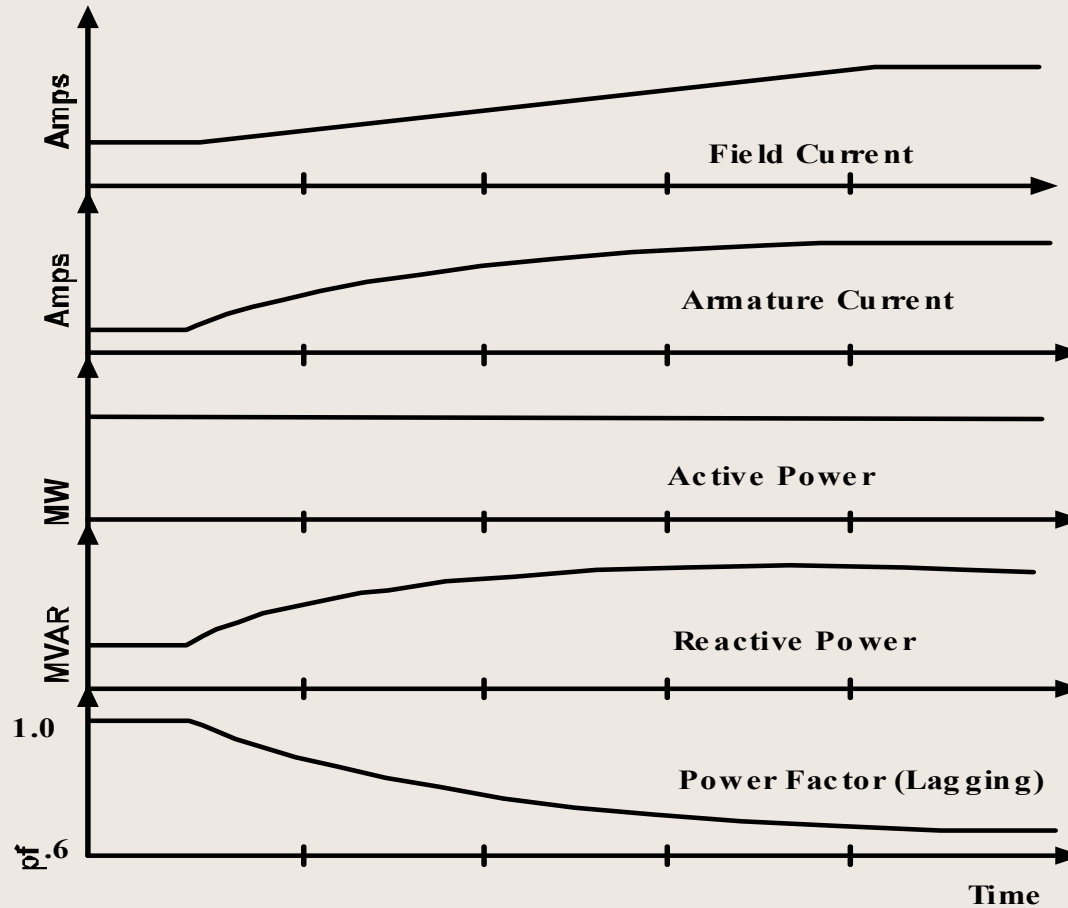




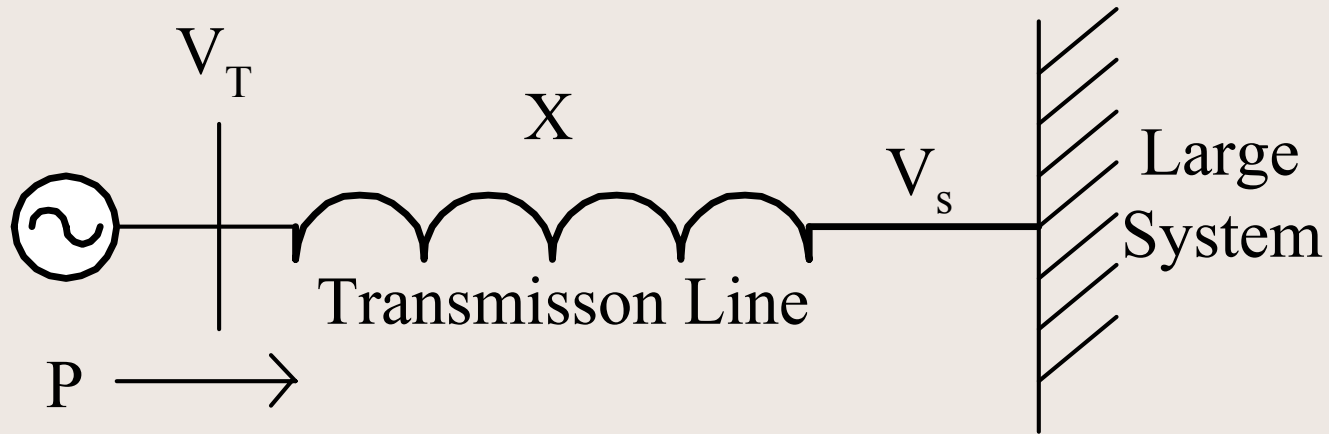
# Adjusting Steam Flow



# Adjusting Excitation

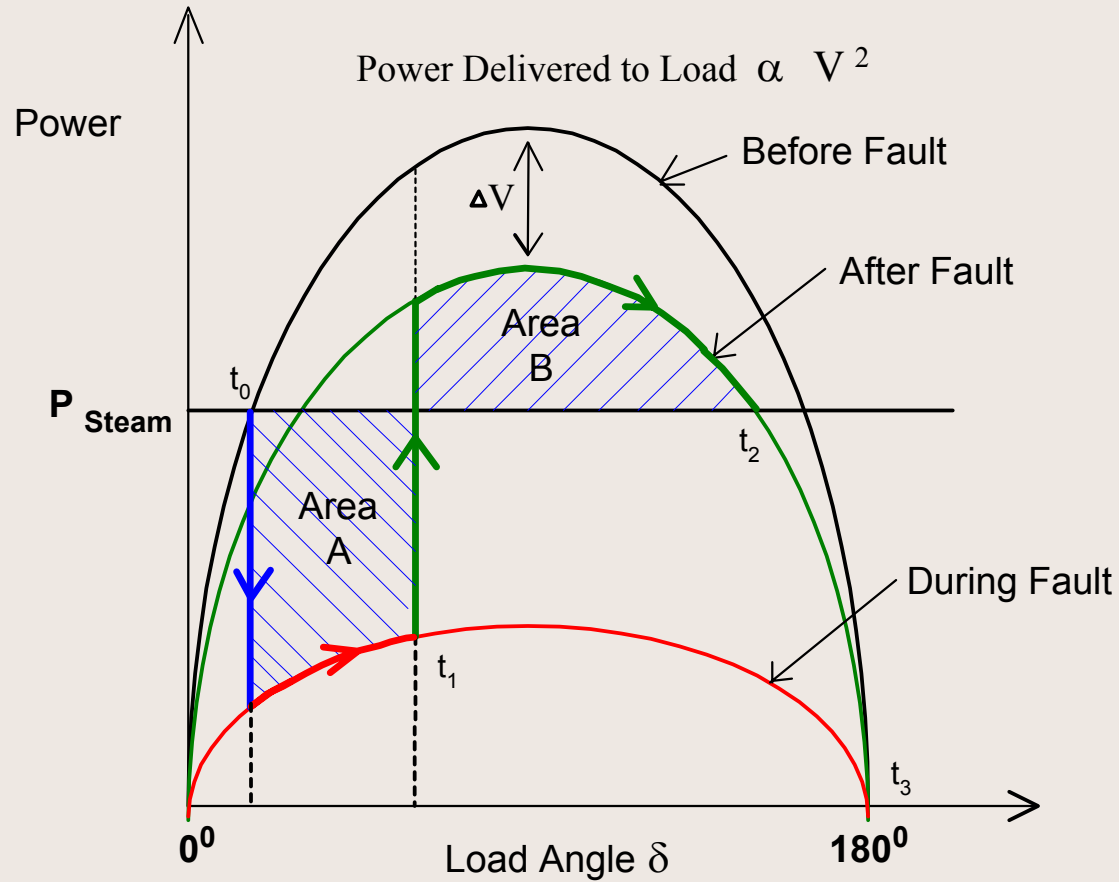


# Stability

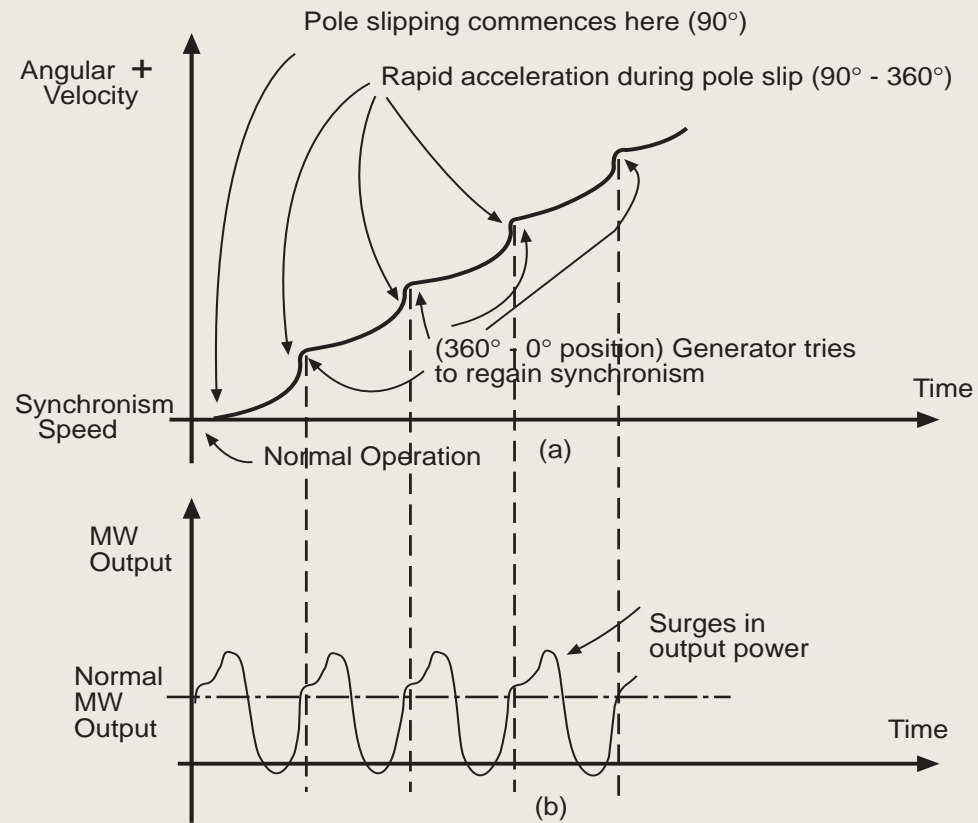


$$P = \frac{V_T V_s}{X} \sin \delta$$

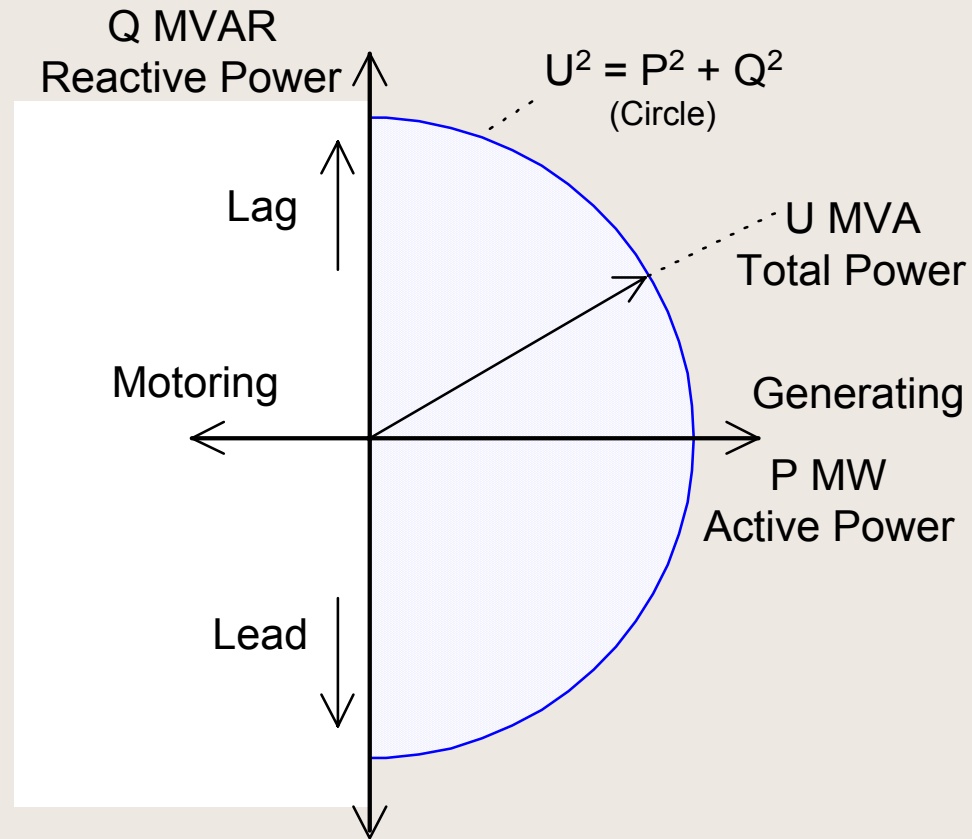
# Power Transfer Curve



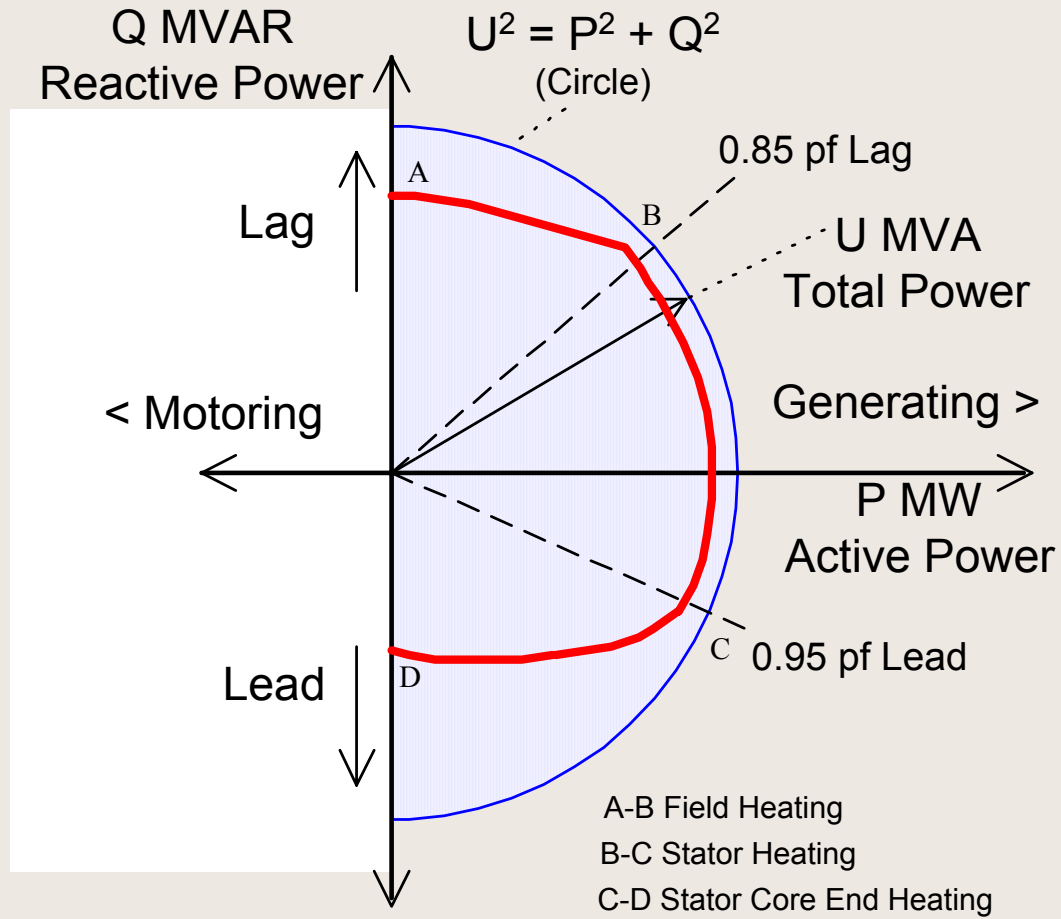
# Out of Step



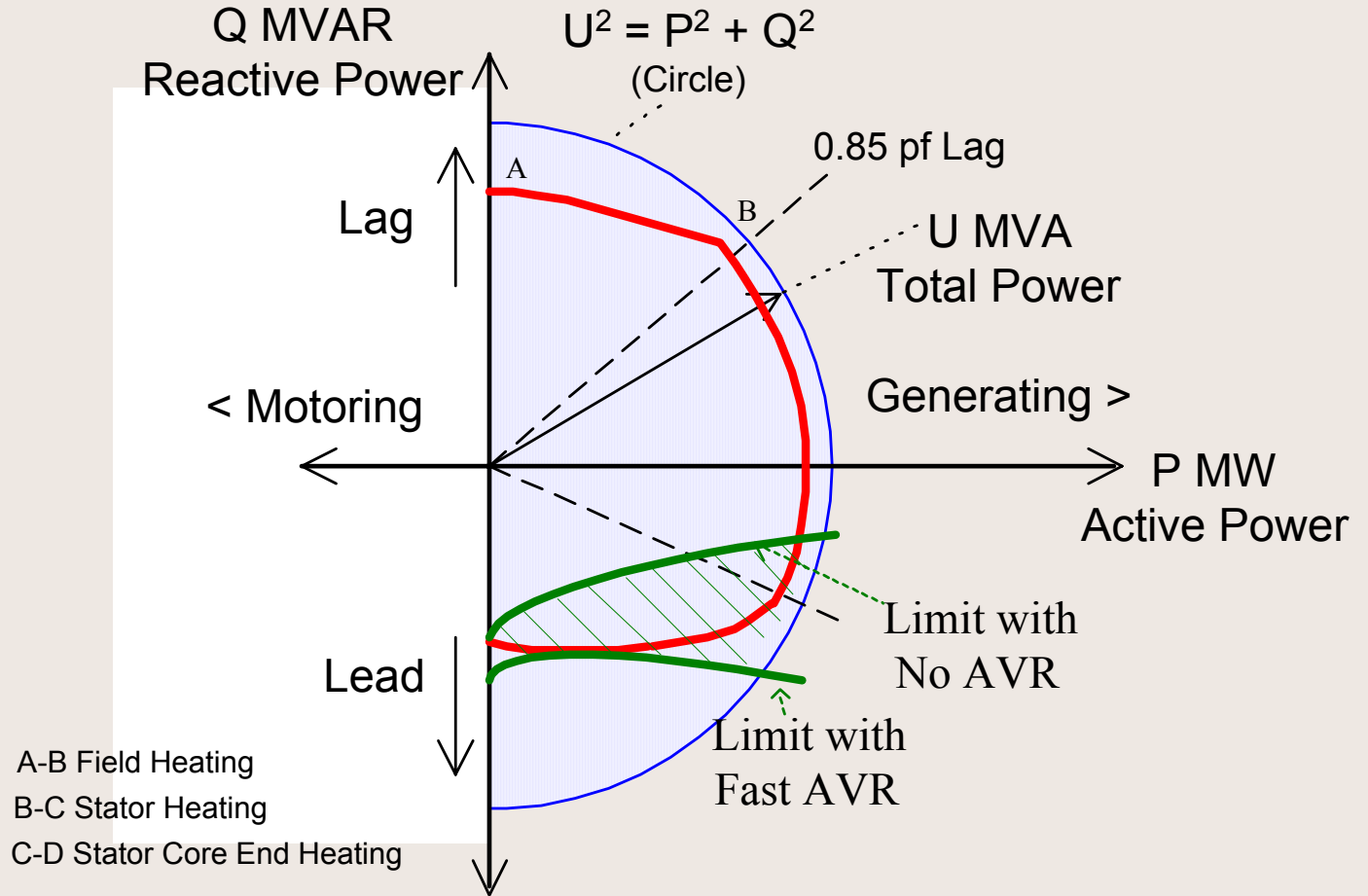
# Generator Heating



# Limits

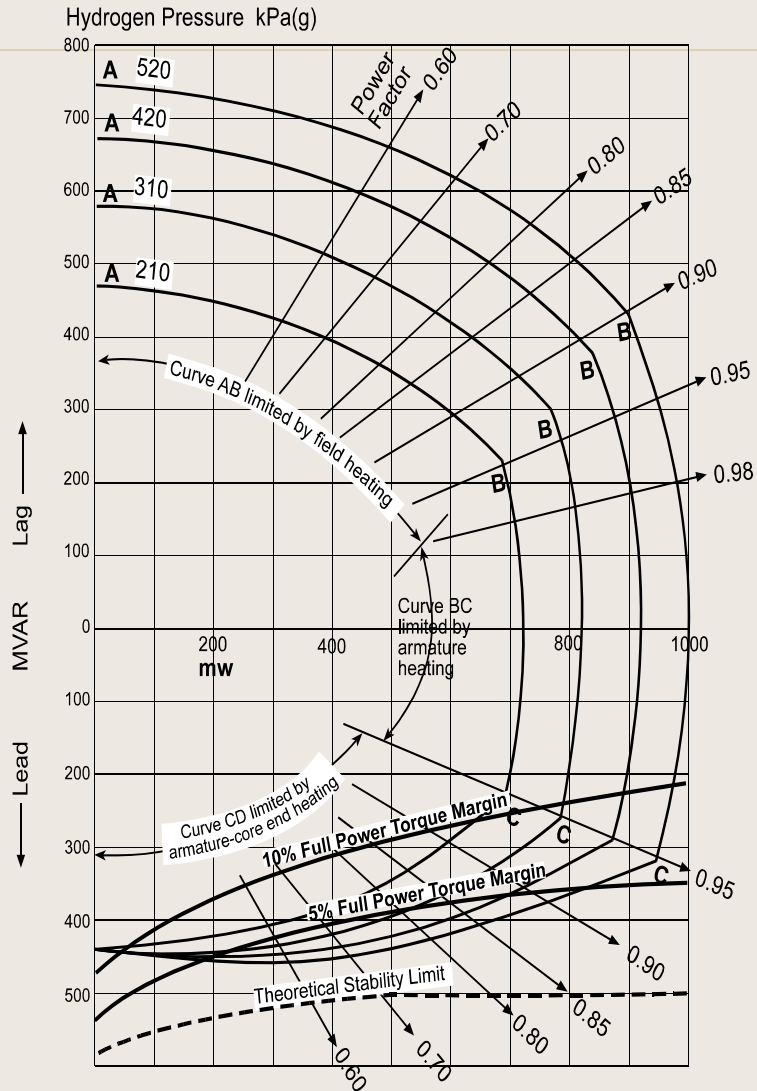


# Stability Limits

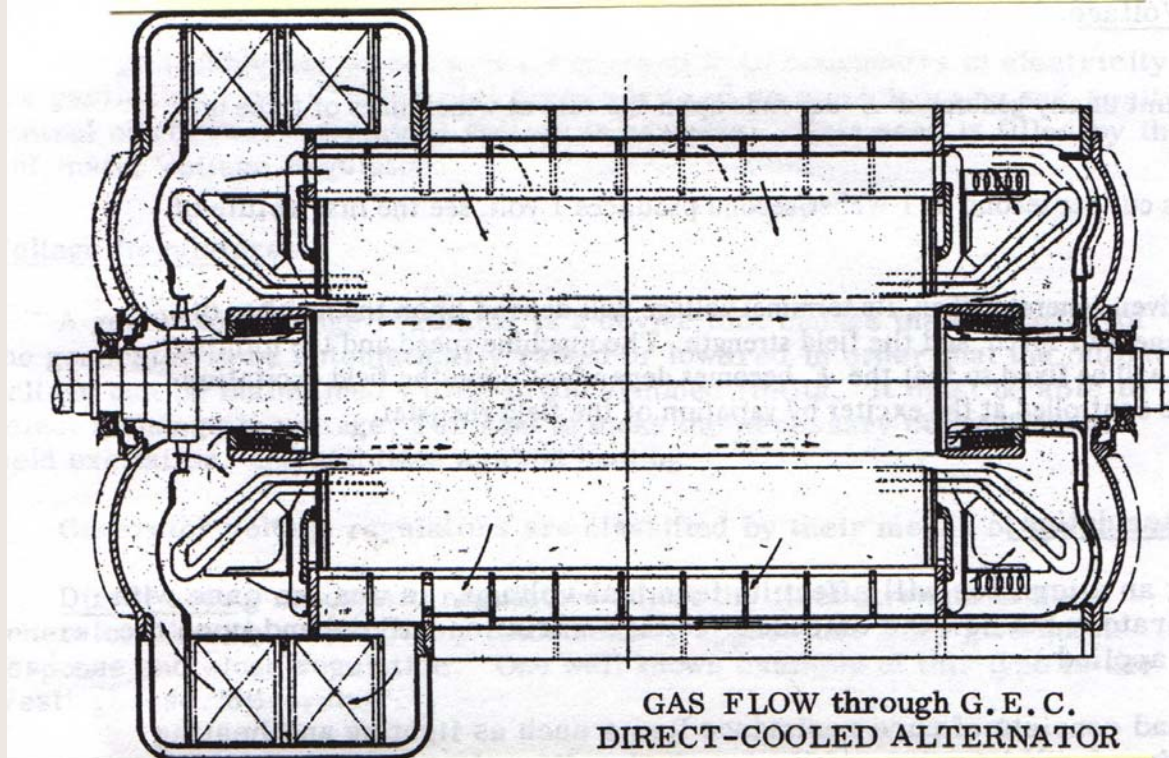




# H<sub>2</sub> Pressure



# Cooling



For You To Do

Questions