36-Single Phase Motors

ECEGR 450
Electromechanical Energy Conversion
Text:10.1-10.2, 10.4, 10.7-10.8

Overview

- Single Phase Induction Motors
- Universal Motors

Introduction

- Majority (~90%) of motors are powered by single phase supplies
  - Households
  - Small businesses
  - Specialty locomotive applications
- Usually <1hp (746W)
- Disadvantages: pulsating torque

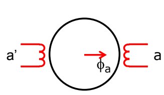
Introduction

Basic Types of Single-Phase AC Motors

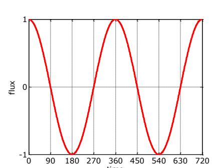
Induction	Universal	Synchronous

Single Phase Induction Motors

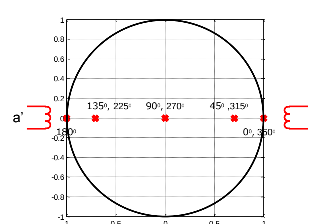
- Recall: poly-phase induction motors use rotating magnetic field to cause rotation
- Single phase supplies produce stationary fields
  - Non-rotational
  - Pulsates with time
- Stator windings are distributed
- Squirrel-cage rotor



stationary, pulsating field



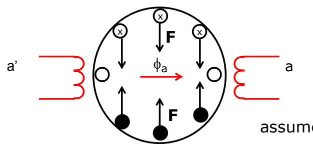
Single Phase Induction Motors



Flux magnitude and direction at ωt =0, 45, 90, … 360 deg

Single Phase Induction Motors

- Single phase induction motors do not inherently self start
- Force experienced by conductors cancel
  - Behaves like a stationary transformer with secondary shorted



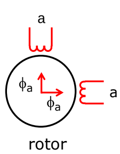
assume ϕ_a is increasing

Single Phase Induction Motors

- Once a single-phase induction motor begins rotating, it will continue
  - See text 10.2 and "cross-field theory"
- We will focus on methods of starting the motor
- Need to create a temporary pseudo-revolving field
  - Split-phase motor
  - Capacitor start motor
  - Capacitor start, capacitor run motor
  - Capacitor run motor
  - Shaded pole motor

Single Phase Induction Motors

Does this arrangement create a revolving field?



Single Phase Induction Motors

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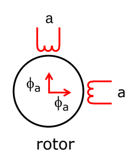
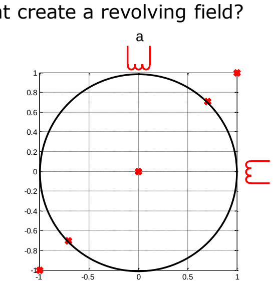
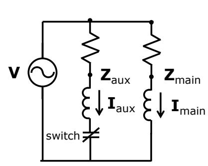




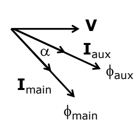
Split-Phase Motors

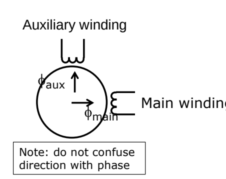
- Idea: use impedance to create two circuit branches with differing phases
- Main winding: lower resistance, high inductance
- Auxiliary winding: higher resistance, lower inductance
- Disconnect auxiliary winding via centrifugal switch at approx. 75% of rated speed (avoid copper loss)



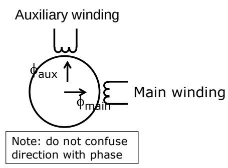
Split-Phase Motors

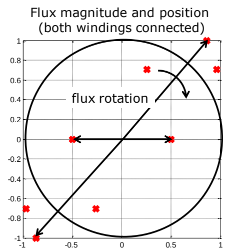
- Auxiliary and main winding currents not necessarily equal
- Phase difference (α) ~25º
  - Small value, lower starting torque
- Revolving field is unbalanced
- Rotation direction can be reversed by reversing connections to auxiliary winding





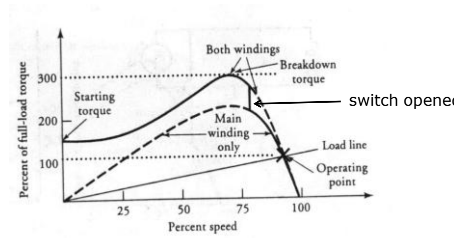
Split-Phase Motors





Unbalanced rotation, small starting torque

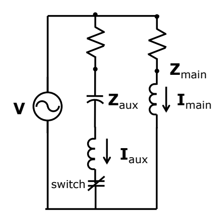
Split Phase Motors

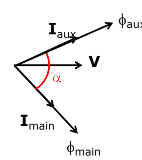


Capacitor Start

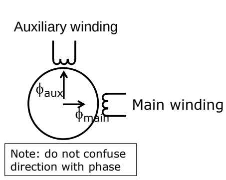
- Same concept as split-phase motor, except use electrolytic capacitor to obtain greater phase shift (~80°) in windings
  - higher starting torque than split phase
  - more expensive than split phase
- Less current than split-phase
- Main winding identical to split phase
- Applications:
  - 120W to 7.5kW
  - Compressors, large fans, pumps, high-inertia loads

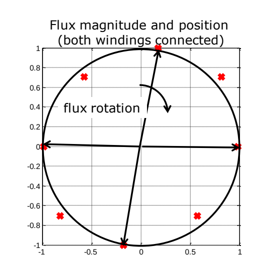
Capacitor Start





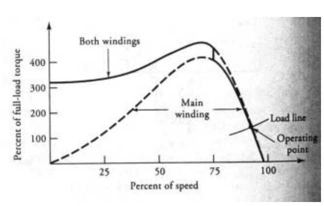
Capacitor Start Motors





Nearly-balanced rotation, higher starting torque

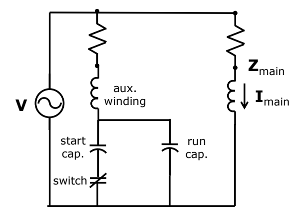
Capacitor Start Motors



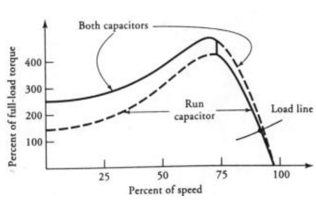
Capacitor Start Capacitor Run

- Split phase and capacitor start induction motors have low power factor at rated speed (aux. winding disconnected)
  - Low efficiency (50% – 60%)
- Solution: improve power factor by utilizing two capacitors
  - Start capacitor: sized based on desired starting torque
  - Run capacitor: sized based on desired running characteristics
- Higher cost motor (switch, two capacitors)

Capacitor Start Capacitor Run



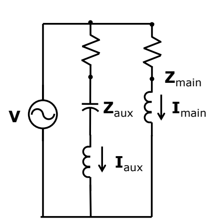
Capacitor Start Capacitor Run



Capacitor Run Motors

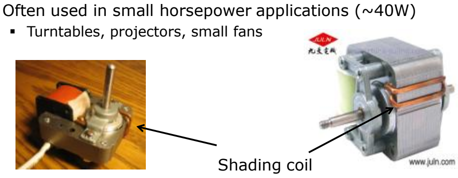
- Idea: leave capacitor and auxiliary winding permanently connected to source
- Trade-off between starting and running characteristics
  - Optimized for running characteristics
- Two windings permanently connected leads to:
  - Consistent torque
  - Quite operation
  - Greater efficiency
- Applications: fans, air conditioners, refrigerators

Capacitor Run Motors



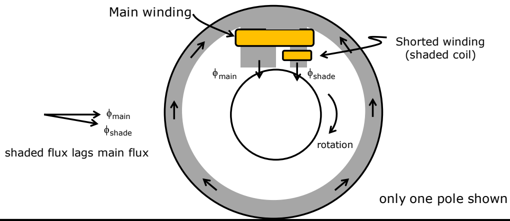
Shaded Pole Motor

- Idea: shift flux using transformer action to create rotating field
- Simple, inexpensive construction
- Low starting torque, power factor, efficiency
- Rotation cannot be changed
- Often used in small horsepower applications (~40W)
  - Turntables, projectors, small fans

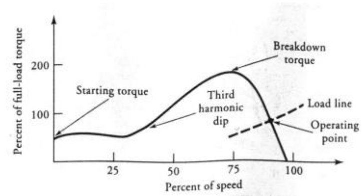


Shaded Pole Motor

- Main winding connected to single-phase source
- Induced current in shaded pole creates flux that opposes change in flux
- Slight phase difference between main and shaded poles



Shaded Pole Motor

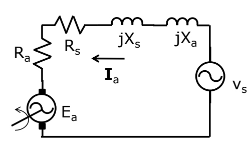


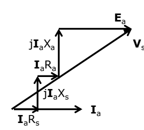
Universal Motors

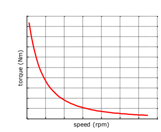
- Powered by AC or DC
  - Similar torque-speed characteristic in either case
- Similar construction as DC Series motor
  - Brushes, commutator
- Similar torque-speed characteristic as DC series motor
- Applications:
  - fractional horsepower motors
  - power tools (e.g. dremmel)
  - vacuum cleaners

Universal Motors

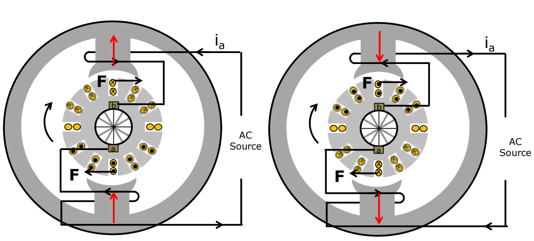
- Circuit Model
  - Torque proportional to $\mathbf{I}_a^2$







Universal Motors



i_a positive

i_a negative

Drawbacks of Universal Motors

- Poles and yoke should be laminated
  - AC fields present, minimize core loss
- Voltage drops and reactive power consumption due to field and armature inductances
  - Decrease number of windings and increase number of armature conductors
- Additional armature conductors increases armature reaction
- Additional sparking of commutator brushes due to transformer action

Universal Motors Advantages

- Suitable for AC or DC operation
- AC motor with potential for high speed operation (>3600 rpm)
- Speed adjusts to load
  - Large load: low speed
  - Small load: high speed