Basic Machine

Day 2

ILOs – Day2

- Realize that a common general theory could be developed that can be used to analyze performance of electrical machines in an unified manner
- Develop basic 2-pole representation for:
  - DC machine
  - Synchronous machine
  - Induction machine

Elements of generalized theory

- Rotating machines are basically the same !!! T/F
- DC motor
- DC generator
- Induction motor
- Induction generator
- Synchronous motor
- Synchronous generator
- Reluctance motor
- AC series motor
- Repulsion motor
- Reluctance motor
- Stepper motor

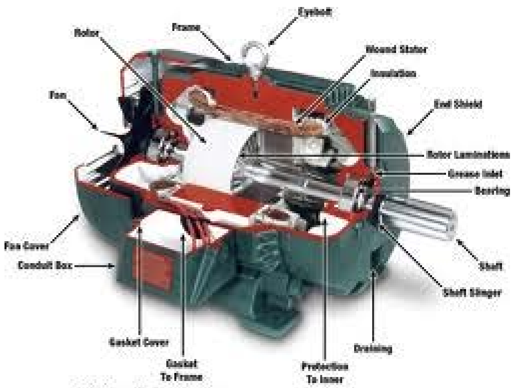
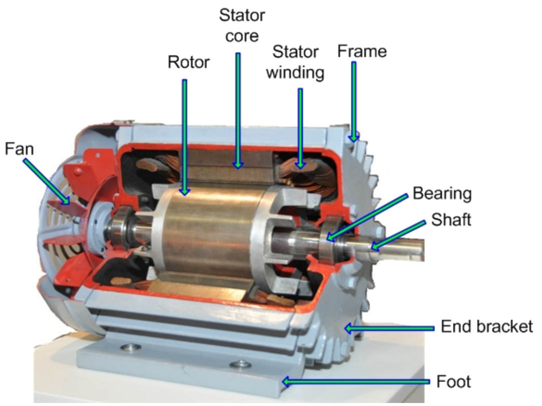
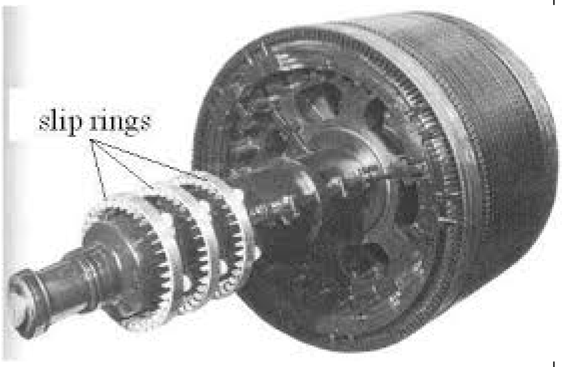
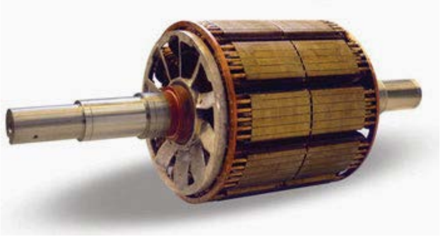


Figure 8 - Motor Construction







Elements of generalized theory

- Rotating machines are basically the same !!! T/F
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- There is an outer stationary part called **stator**
- Inner rotating part called **rotor**
- Rotor is mounted on **bearings** fixed with stator
- They rotate relative to one another enabling **electromechanical energy conversion**
- Both stator and rotor have concentric **ferromagnetic core**
  - May or may not be laminated
  - May or may not have slots/teeth
  - May or may not have salient (projected) poles
- Small **air gap** between stator and rotor
- Stator and rotor have conductors that are suitably connected to form windings
- Stator and rotor has a **mutual magnetic flux** that links both across the air gap

Elements of generalized theory

- Rotating machines are basically the same !!! T / F
- Differences in:
  - Construction
  - Winding arrangements
  - Types of excitation

Elements of generalized theory

- Rotating electrical machines work on the same basic principles
- Thus, is there an **unified method** possible that can analyze operation of all machines?
  - Generalized theory of electrical machines
  - Two-axis theory of electrical machines
- Systematic treatment of all rotating electrical machines

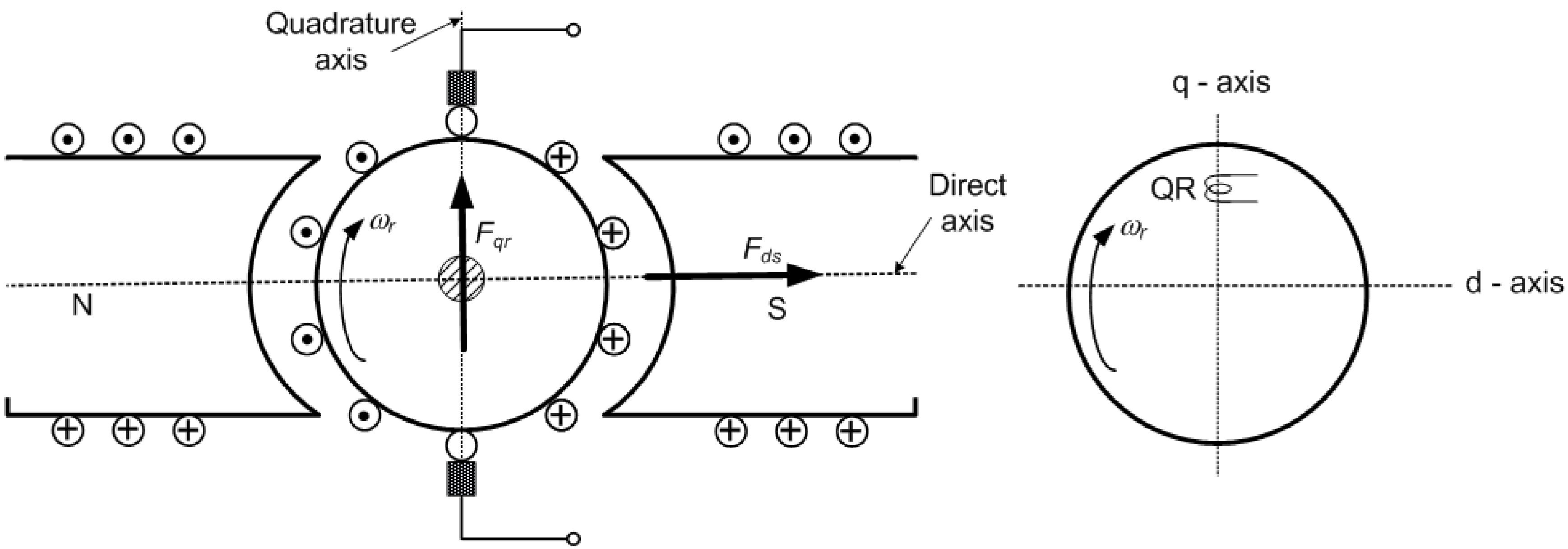
- Pioneering Engineers
  - Robert H. Park (US, 1902 – 1994)
  - Gabriel Kron (US, 1901 – 1968)
  - Vladimir Karapetoff (Russia 1876 – 1948)

Conventions for generalized theory

- Flux distribution under one pole pair is similar for other pole pairs
  - All machines are treated as two-pole equivalent
- Any closed winding is represented by a single coil
  - Three coils for 3-phase machine
  - One coil for single phase machine (or DC machine)
- Pole axis is called **direct axis** (d axis)
- Axis perpendicular to pole is called **quadrature axis** (q axis)
- Positive rotor movement is taken in clockwise direction

Basic 2-pole representations

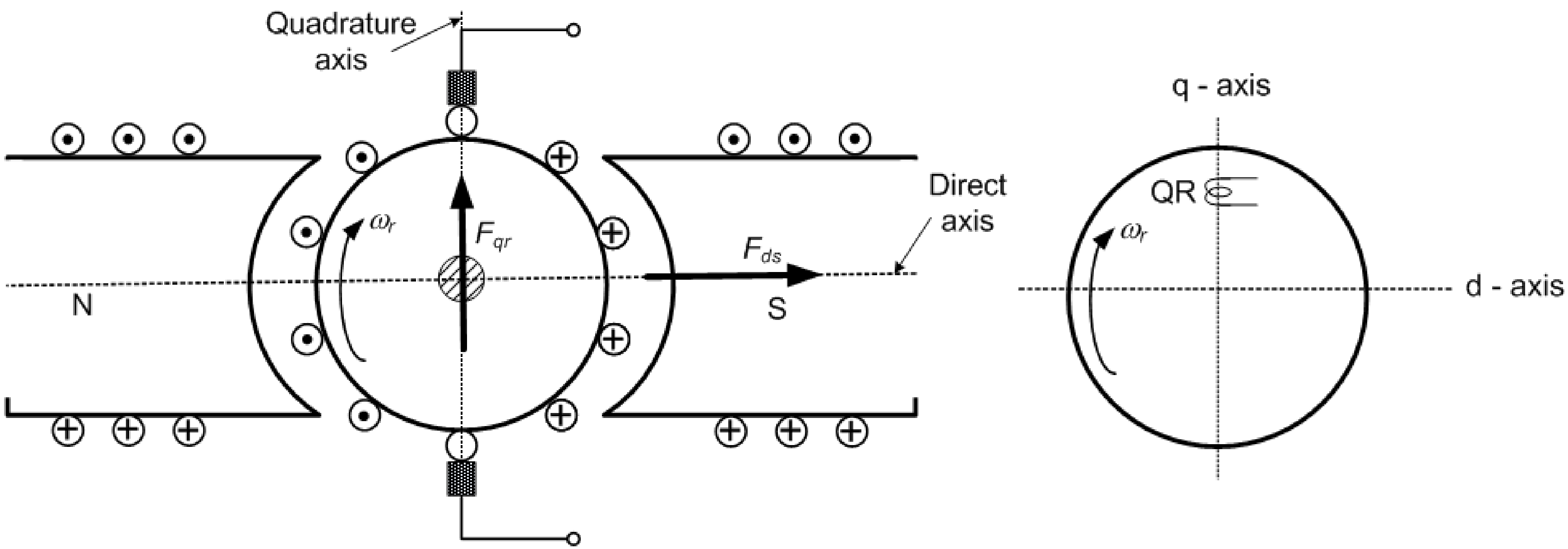
- **Separately excited DC machine**



- Current distribution in the armature (rotor) coil always remain unchanged w.r.t. the brushes & poles even when the rotor rotates
  - (Any rotor coil that comes under N pole will have "dot" and that under S pole will have "cross" – even as the armature rotates)
- Thus, armature coil can be represented by a single **stationary** coil with axis along the q-axis (brush axis) – represented by QR (**Q**-axis and **R**otor)

Basic 2-pole representations

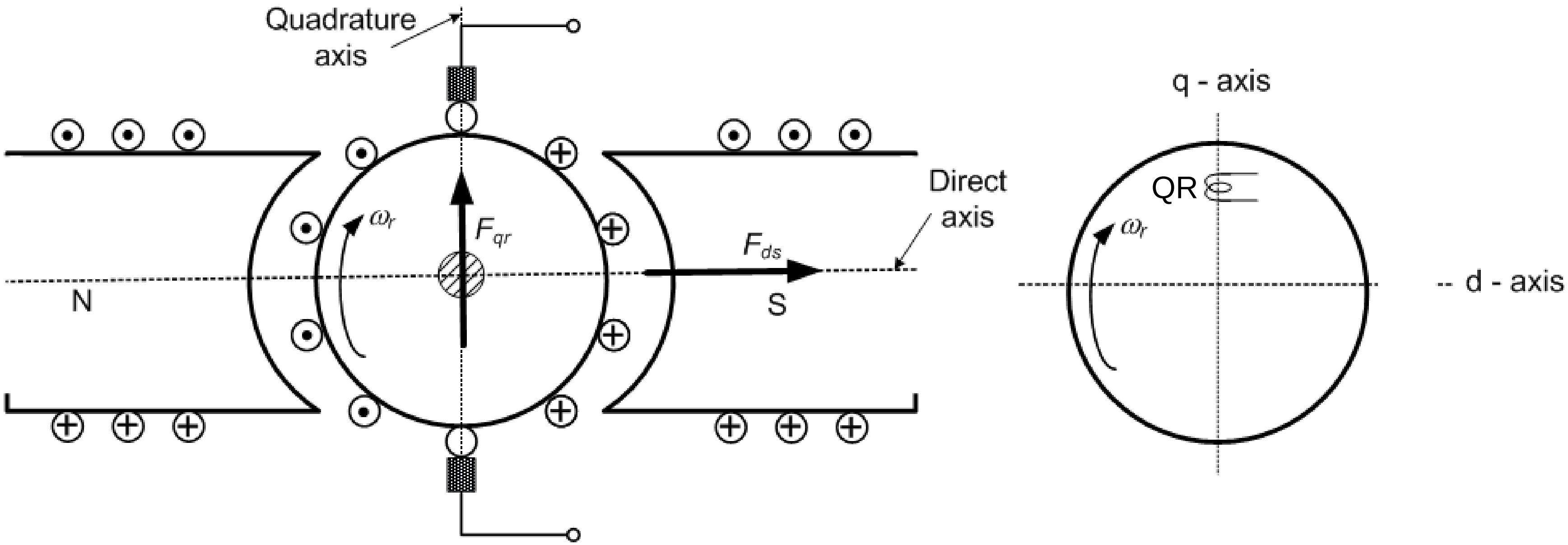
- **Separately excited DC machine**



- The armature coil QR is called *pseudo-stationary* coil, or *quasi-stationary* coil
  - In reality it moves around as rotor moves
  - But, due to commutator, the rotor coil produces MMF that is stationary in space (along Q axis)

Basic 2-pole representations

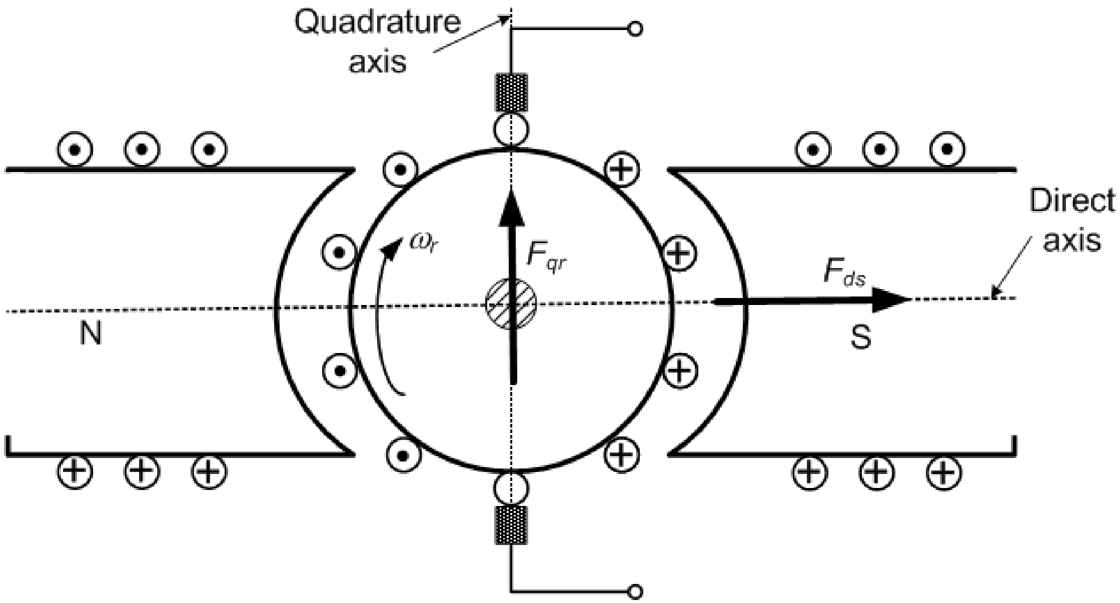
- **Separately excited DC machine**

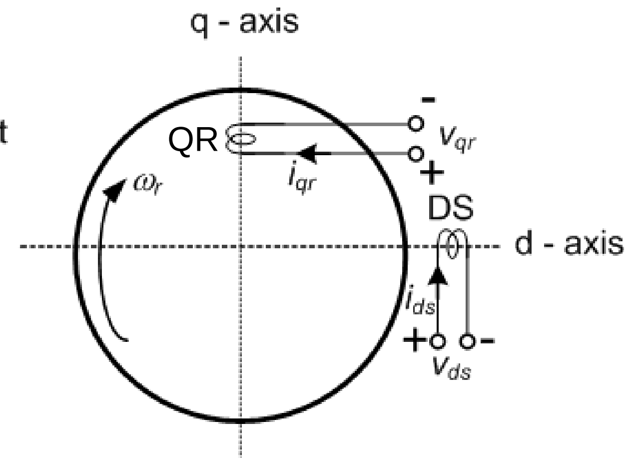


- Field coils on the poles is represented by a single stationary coil DS (**D**-axis and **S**tator) that produces same MMF as the poles
  - Hence producing same EMF in generator mode
  - Same Torque in motor mode

Basic 2-pole representations

- **Separately excited DC machine**

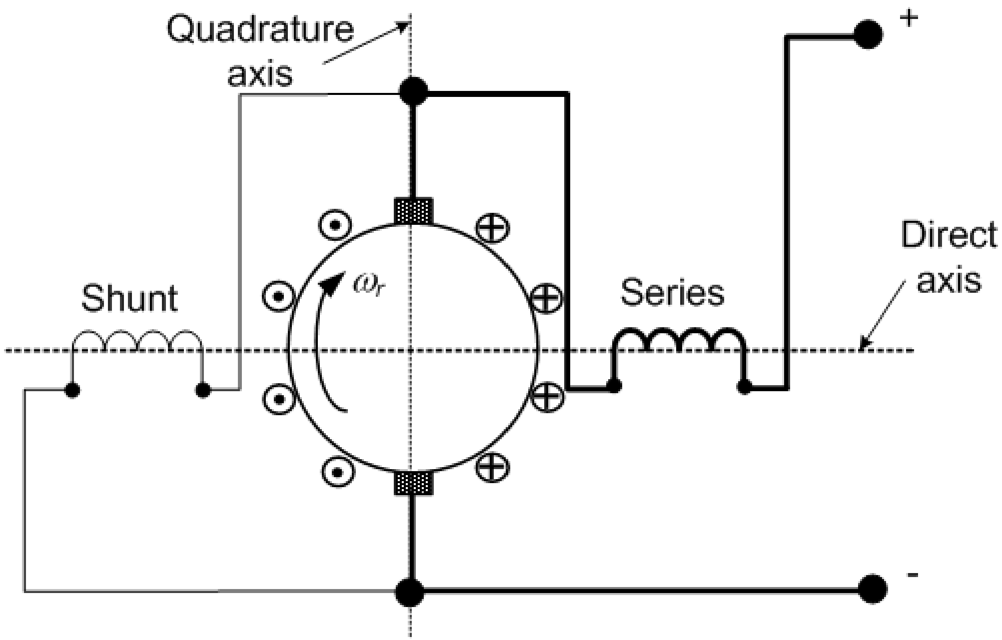


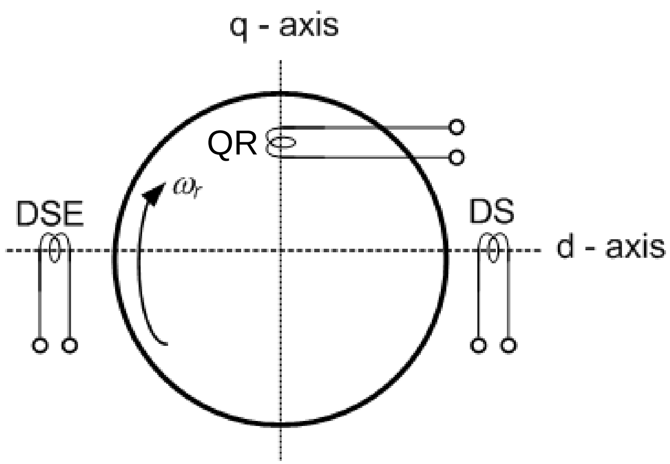


- v_{ds} – Field supply voltage
- v_{qr} – Armature supply voltage (motor mode)
- i_{ds} – Field supply current
- i_{qr} – Armature supply current (motor mode)

Basic 2-pole representations

- **DC compound machine**

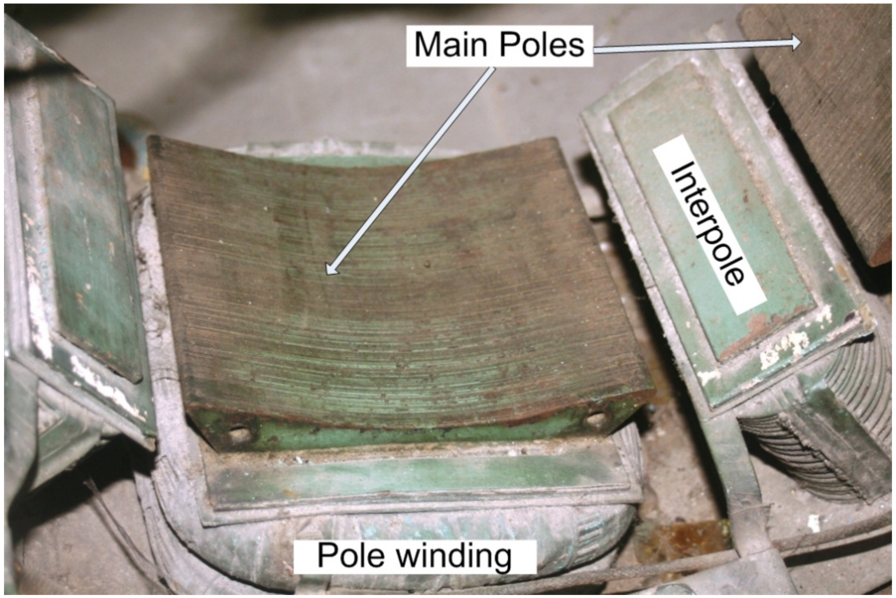


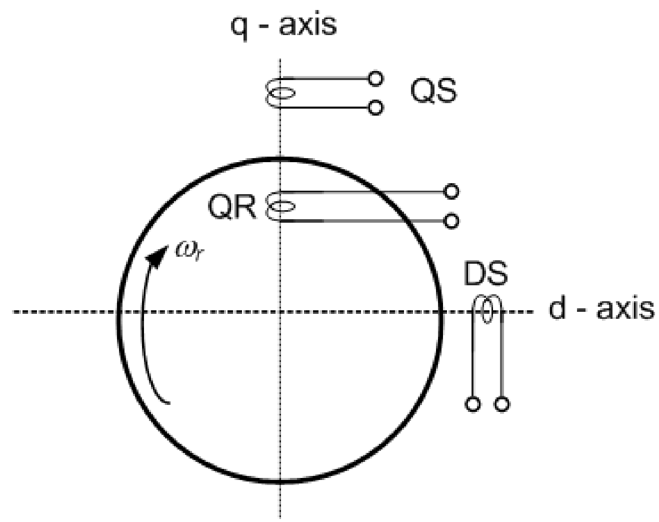


- DSE – Series field coil on the main poles
- DS – Shunt field coil on the main poles

Basic 2-pole representations

- **DC shunt machine with interpoles**

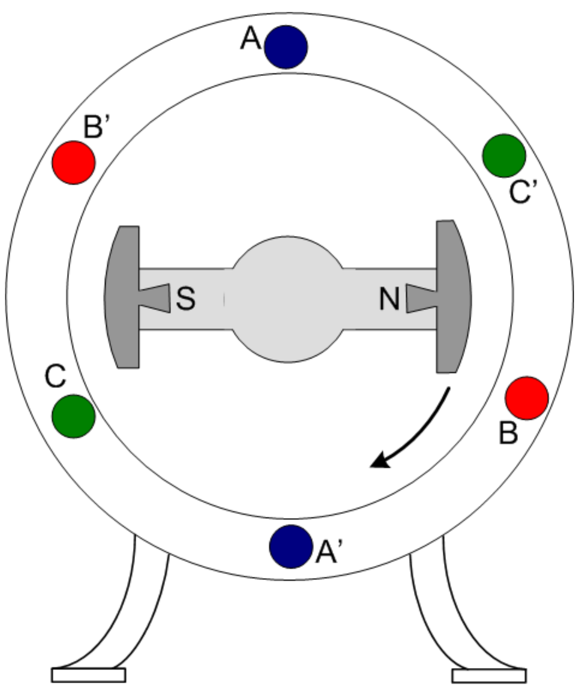




- Interpoles are small poles placed in stator between two main poles
  - They are used to reduce the effects of armature reaction
  - Axis of interpole MMF is 90^0 away from that of main pole MMF
- Interpole field coils are represented by a single stationary coil QS (**Q**-axis and **S**tator) that produces same MMF as the interpoles

Basic 2-pole representations

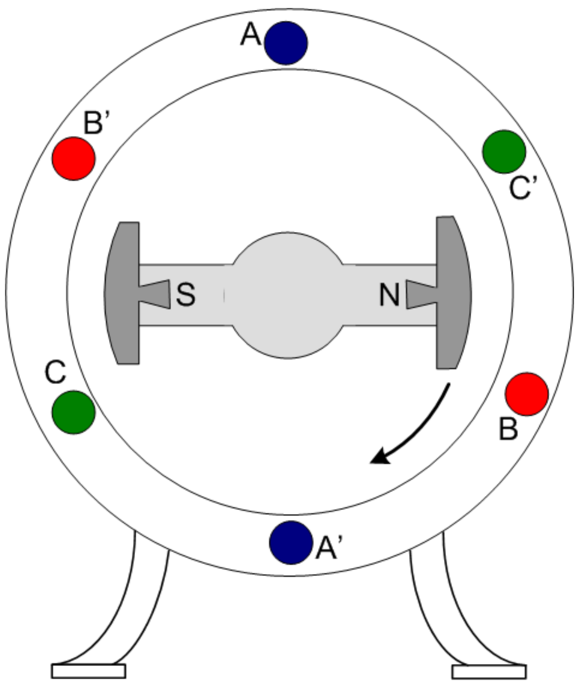
- **3-phase synchronous machine**
  - One field coil (DC) – generally in the rotor – external DC supply is provided through slip ring and brushes
  - Three windings in stator for carrying 3-phase power

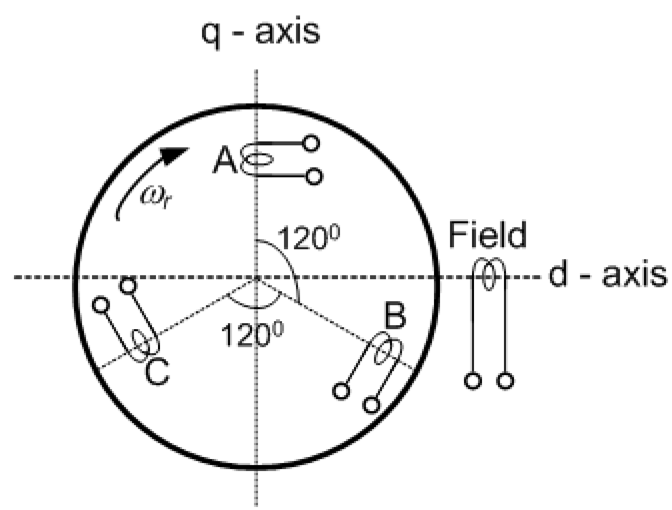


- Equivalent 2-pole representation, it is convenient if field is taken in stator and the 3-phase armature in rotor
- Machine analysis will remain same since we need only need relative motion between stator and rotor
- In fact some small synchronous machines do have field in stator and 3-phase armature in rotor

Basic 2-pole representations

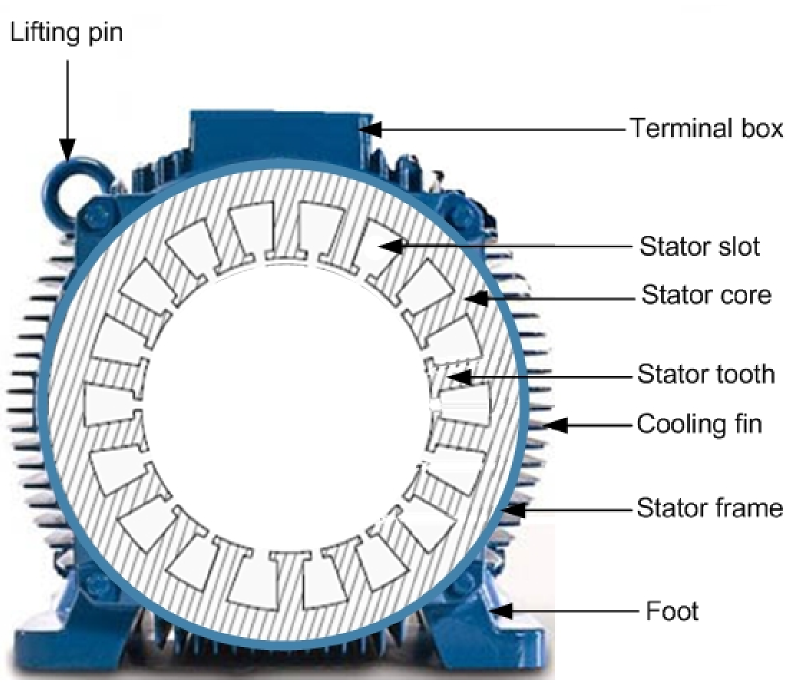
- **3-phase synchronous machine**
  - Field is taken in stator and the 3-phase armature in rotor
    - Field winding is represented by a single stationary coil "Field" in stator along d-axis
    - Three armature coils A, B, C mutually at 120^0 placed in rotor represent the armature 3-phase coils (they are **not** pseudo-stationary since there is no commutator)

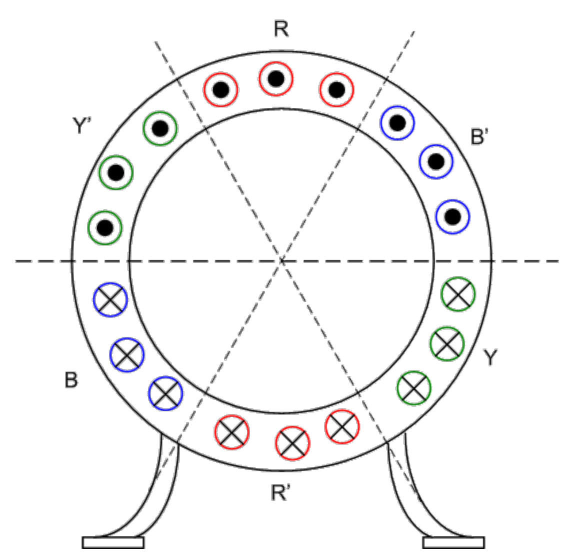




Basic 2-pole representations

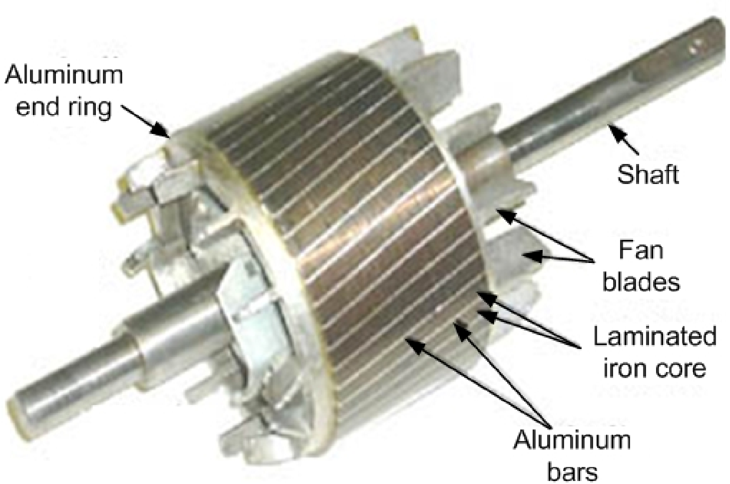
- **3-phase induction machine**
  - 3-phase winding in stator that produces rotating magnetic field (RMF) in the air gap

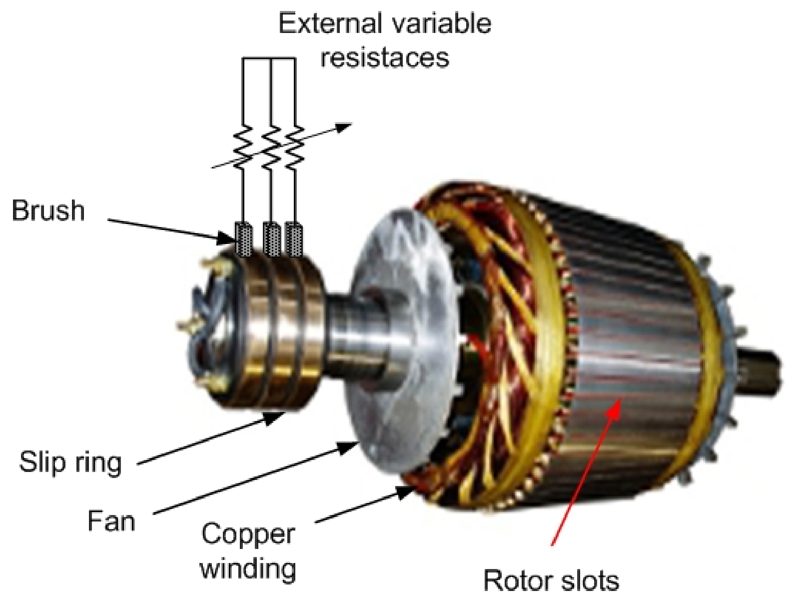




Basic 2-pole representations

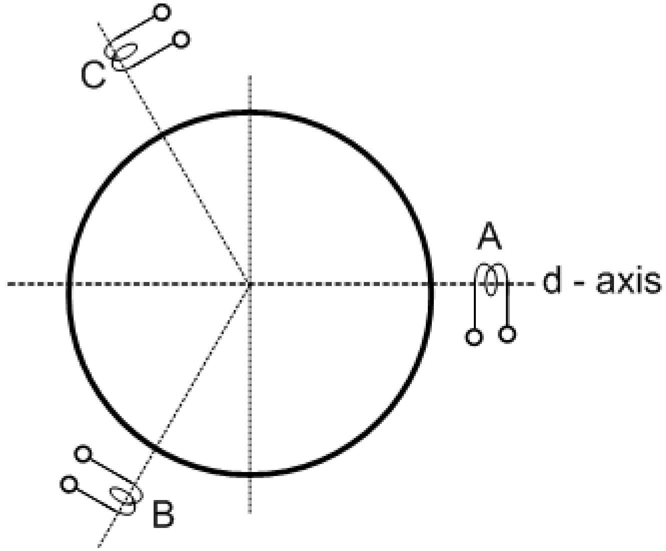
- **3-phase induction machine**
  - 3-phase winding in stator that produces rotating magnetic field (RMF) in the air gap
  - Whether it is squirrel cage type or wound rotor type, the rotor also has a 3-phase winding





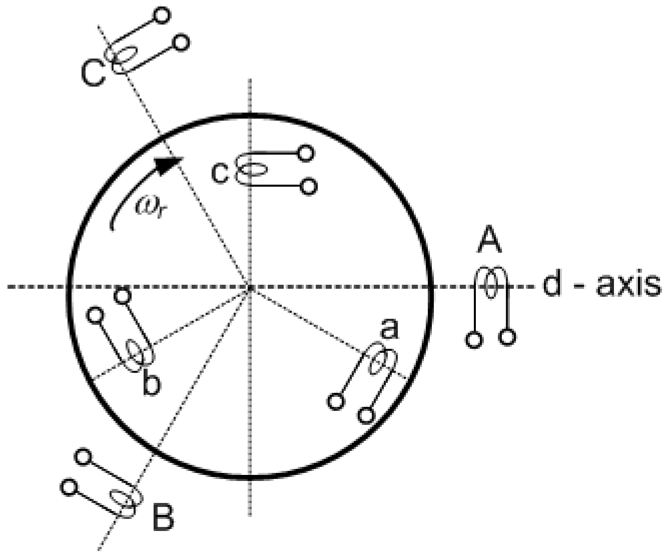
Basic 2-pole representations

- **3-phase induction machine**
  - 3-phase winding in stator that produces rotating magnetic field (RMF) in the air gap
    - Represented by three stator coils A, B, C placed 120^0 apart in space
    - Phase A coil can be taken along d-axis for convenience



Basic 2-pole representations

- **3-phase induction machine**
  - Whether it is squirrel cage type or wound rotor type, the rotor also has a 3-phase winding
    - Represented by three coils a, b, c placed 120^0 apart in space
    - Orientation of rotor coils (a, b, c) w.r.t the stator coils (A, B, C) is arbitrary



Basic 2-pole representations

- Observations
  - We can draw 2-axis generalized representation of any rotating machine if we know its stator & rotor configuration
  - Salient pole structure is generally taken as stator
  - Winding arrangements in stator and rotor
  - Presence and position of brushes (if present) – along Q axis
  - Slot-tooth arrangement is not considered