Synchronous Motors

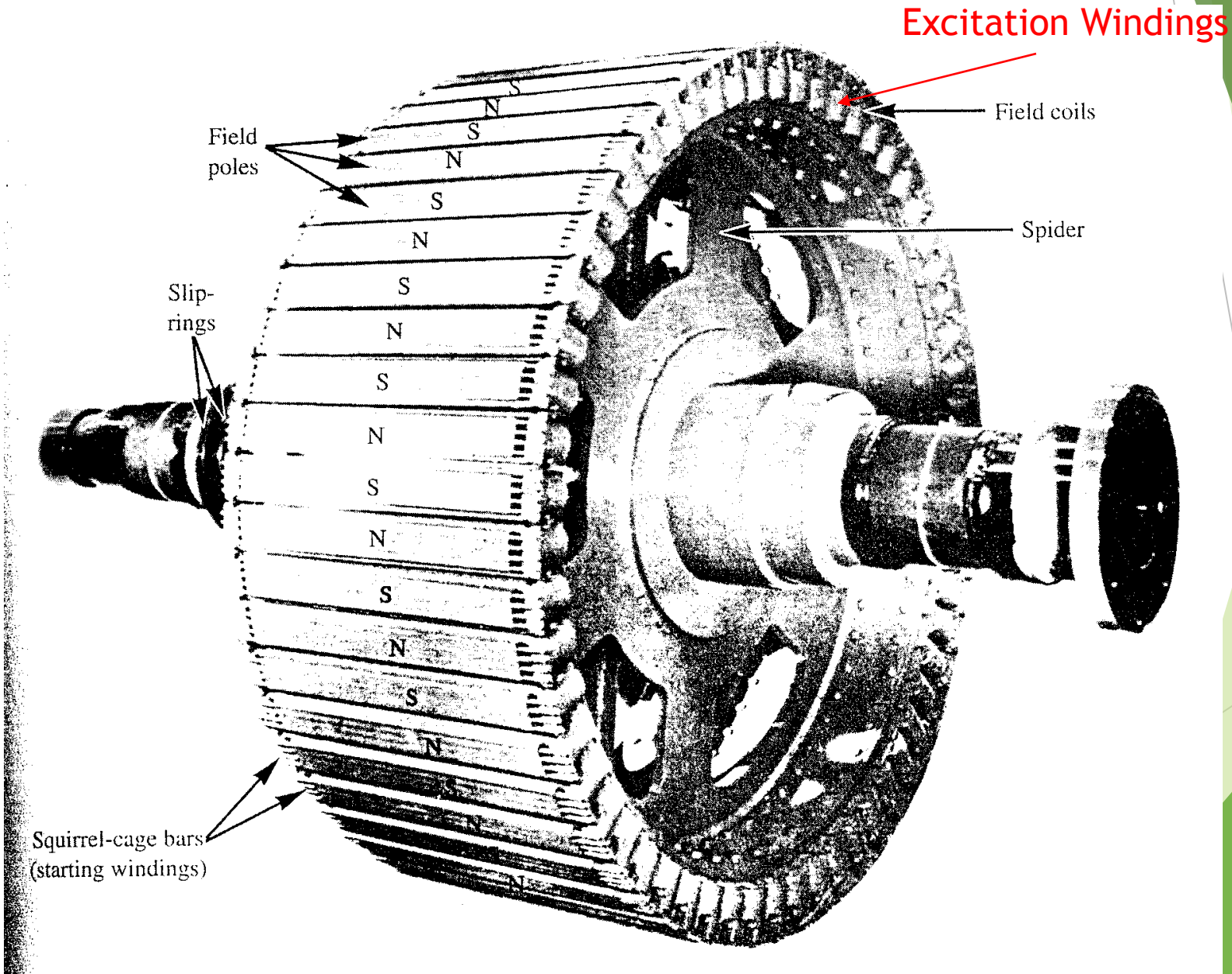
Synchronous Motors (continued)

- Construction
  - Stator identical to that of a three-phase induction motor – now called the “armature”
  - Energize from a three-phase supply and develop the rotating magnetic field
  - Rotor has a DC voltage applied (excitation)
  - Rotor could be a permanent-magnet type

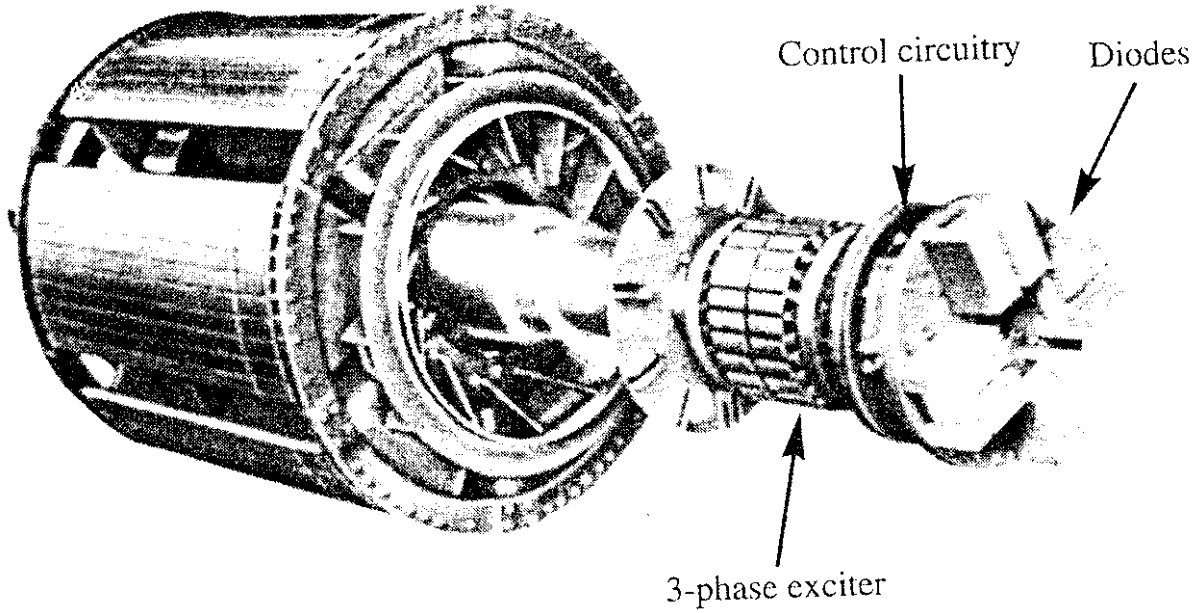
Synchronous Motors (continued)

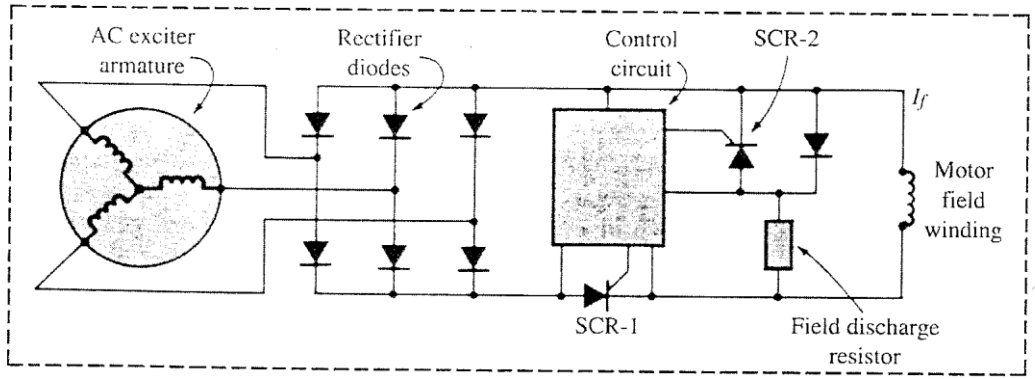
- Operation
  - Magnetic field of the rotor “locks” with the rotating magnetic field – rotor turns at synchronous speed

Salient-Pole Rotor



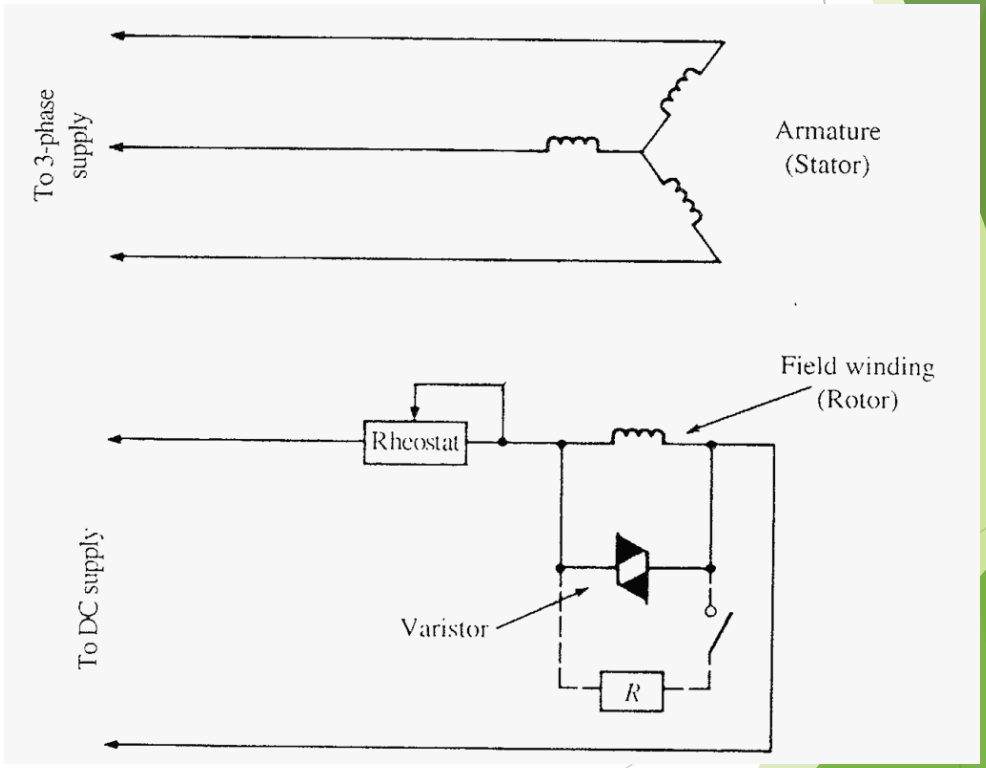
Salient-Pole Rotor with brushless excitation



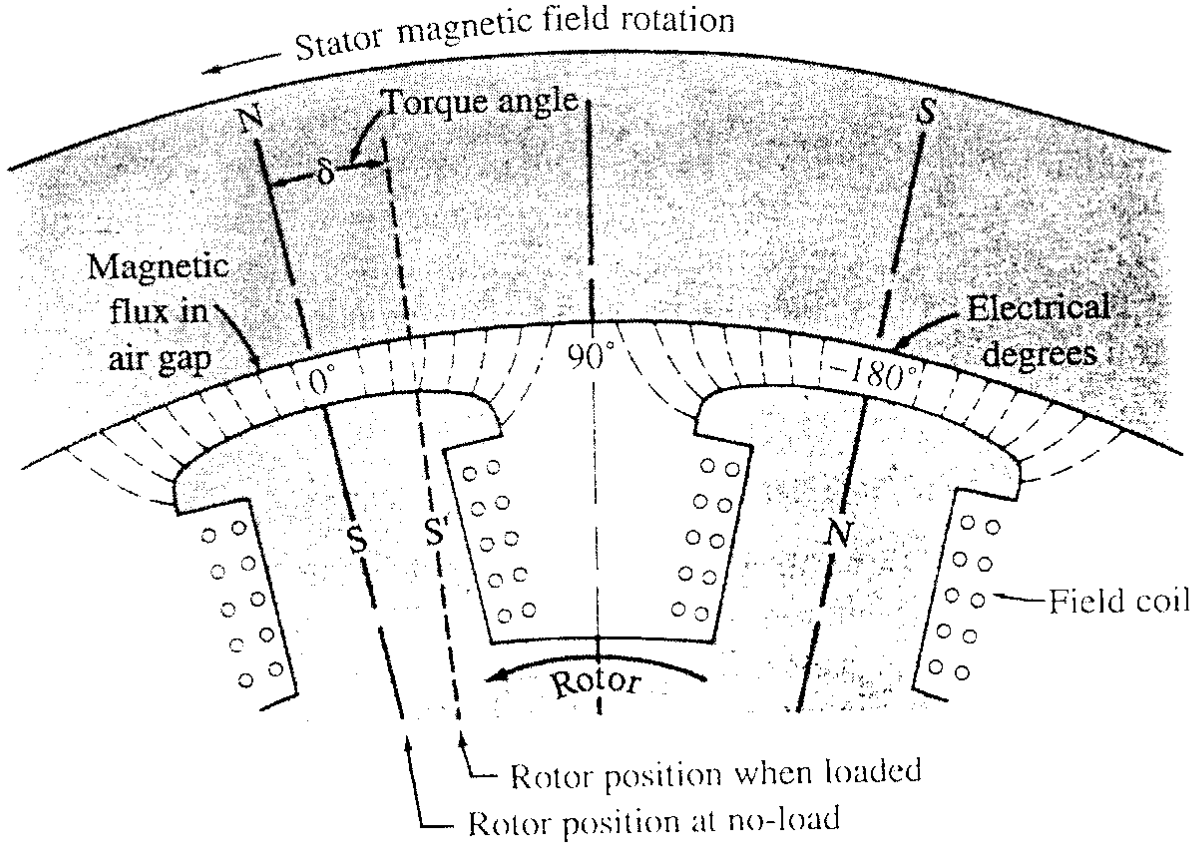


Synchronous Motor Starting

- Get motor to maximum speed (usually with no load)
- Energize the rotor with a DC voltage

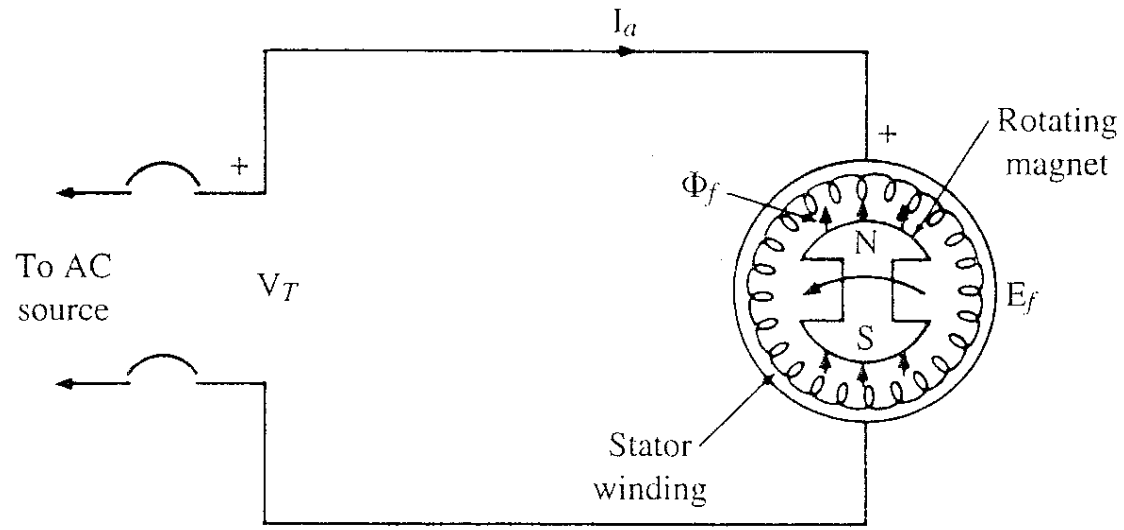


Salient-Pole Motor operating at both no-load and loaded conditions



Angle δ is the ***power angle***, ***load angle***, or ***torque angle***

Rotating Field Flux and Counter-emf



- Rotating field flux Φ_f due to magnetic field in the rotor. A "speed" voltage, "counter-emf", or "excitation" voltage E_f is generated and acts in opposition to the applied voltage.
- $E_f = n_s \Phi_f k_f$

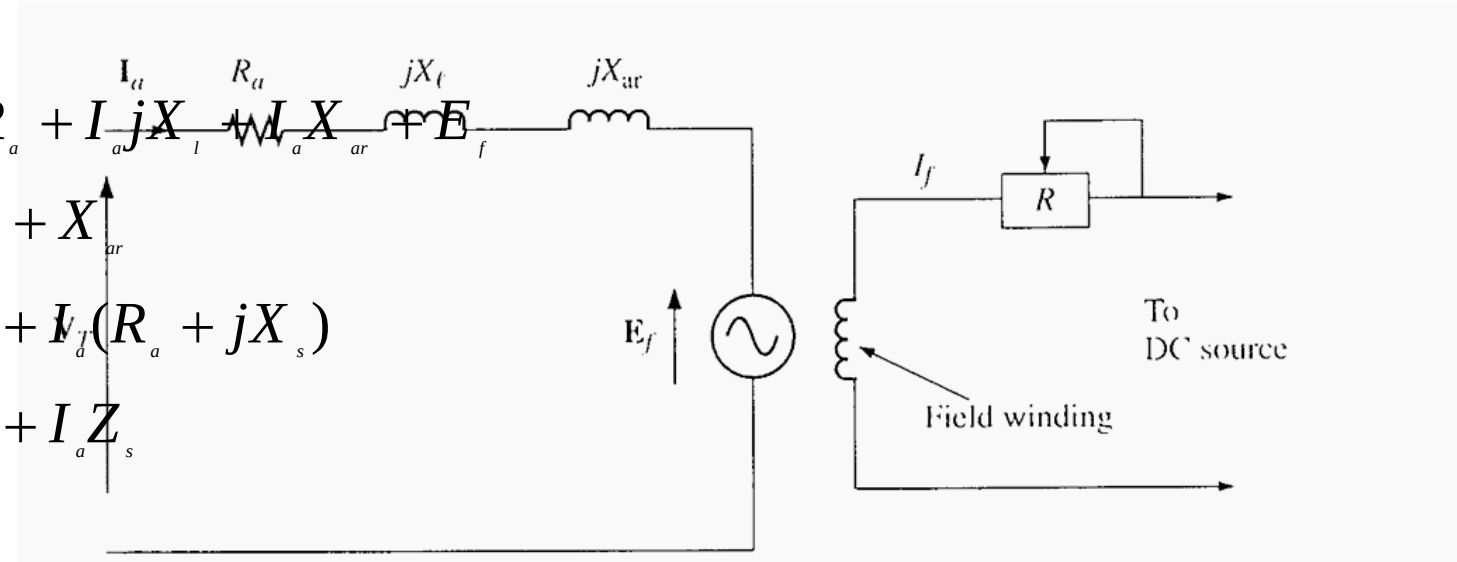
Equivalent Circuit of a Synchronous Motor Armature (One Phase)

$$V_T = I_a R_a + I_a jX_l + I_a jX_{ar} + E_f$$

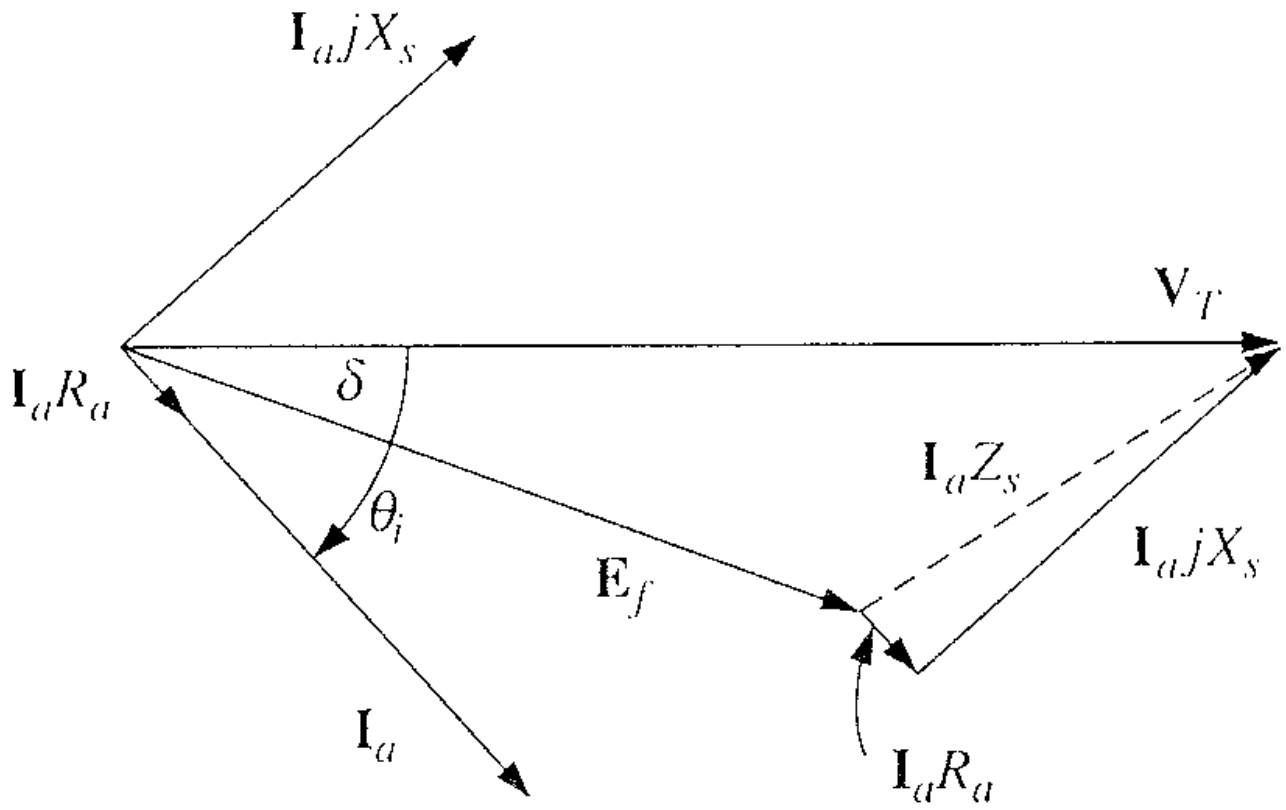
$$X_s = X_l + X_{ar}$$

$$V_T = E_f + I_a(R_a + jX_s)$$

$$V_T = E_f + I_a Z_s$$

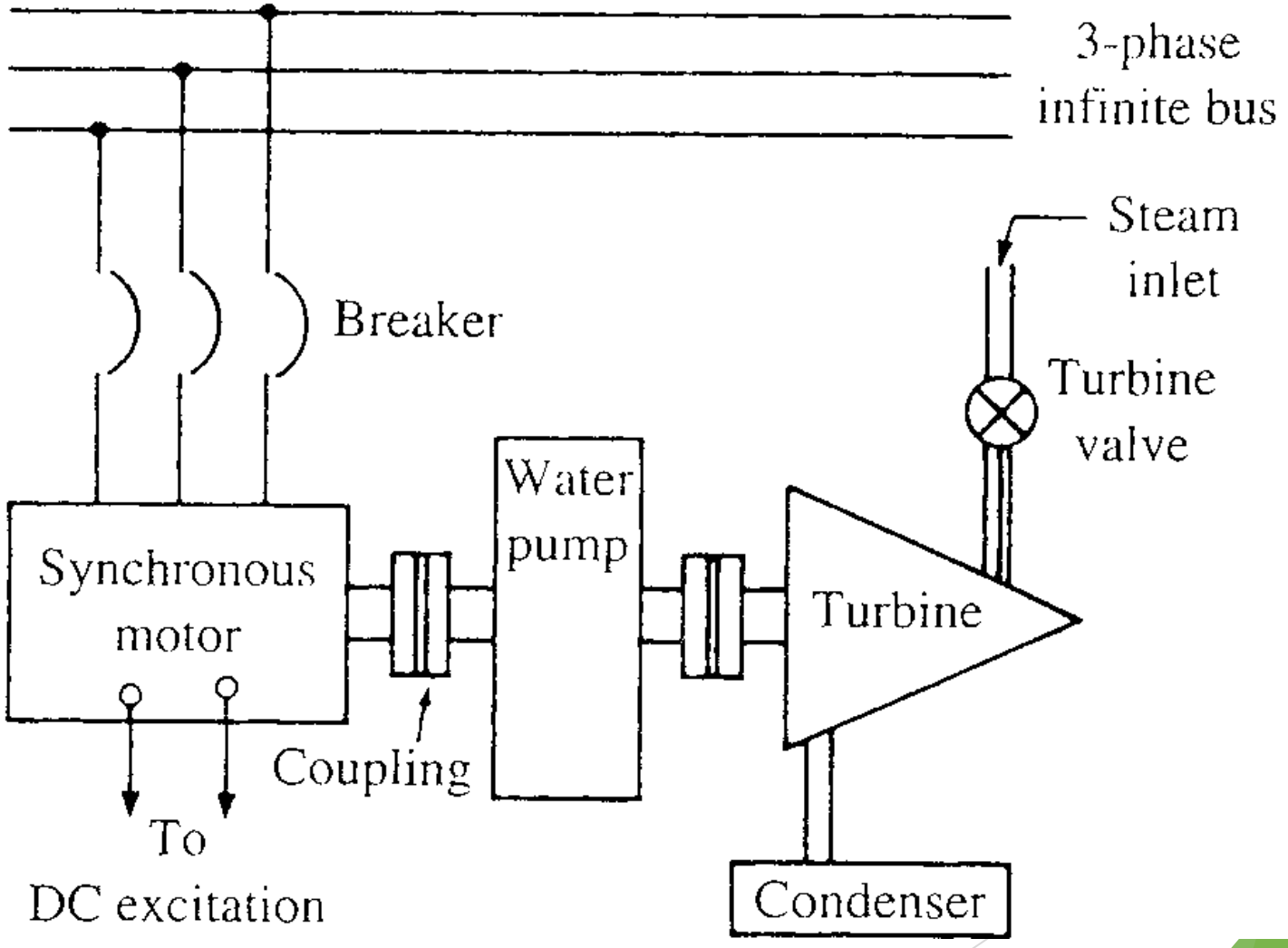


Phasor Diagram for one phase of a Synchronous Motor Armature



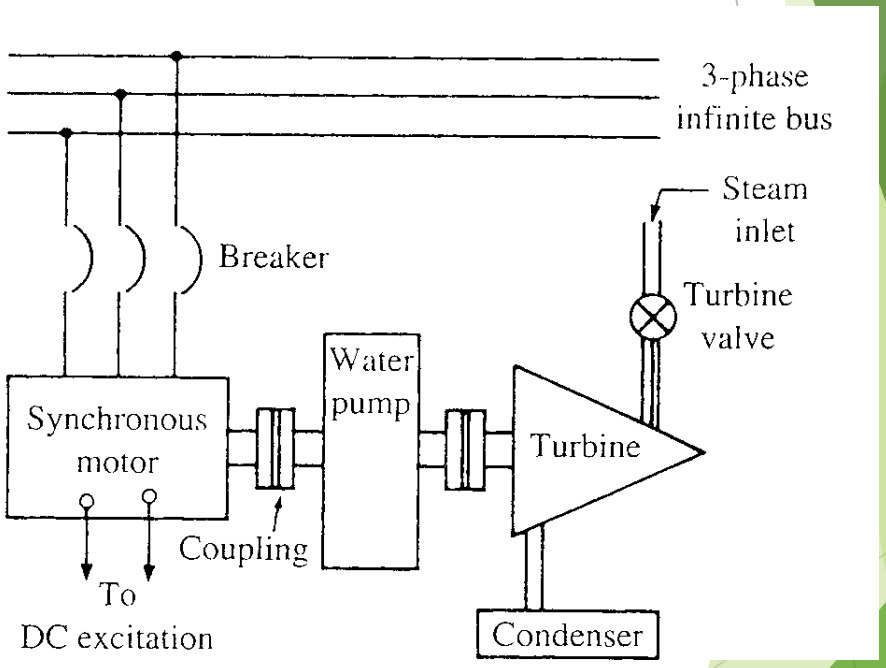
Synchronous Generators

Motor-to-Generator Transition



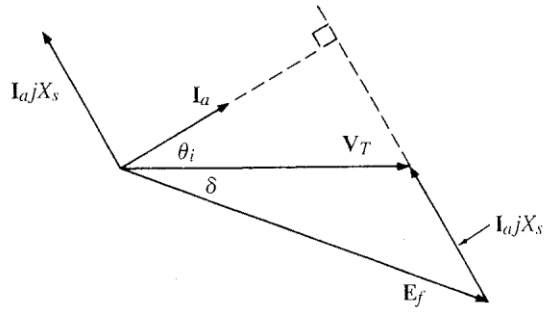
Motor-to-Generator Transition (cont)

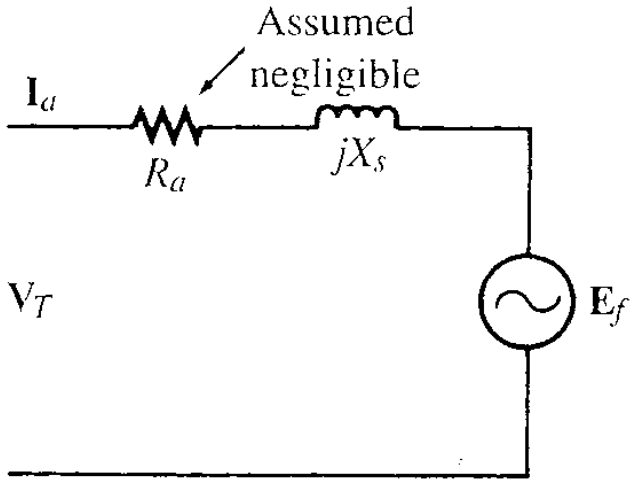
- Begin with motor driven from the infinite bus and the turbine torque in the same direction as the motor torque.
- The motor operates normally, driving the water pump.



Motor-to-Generator Transition (cont)

Phasor Diagram

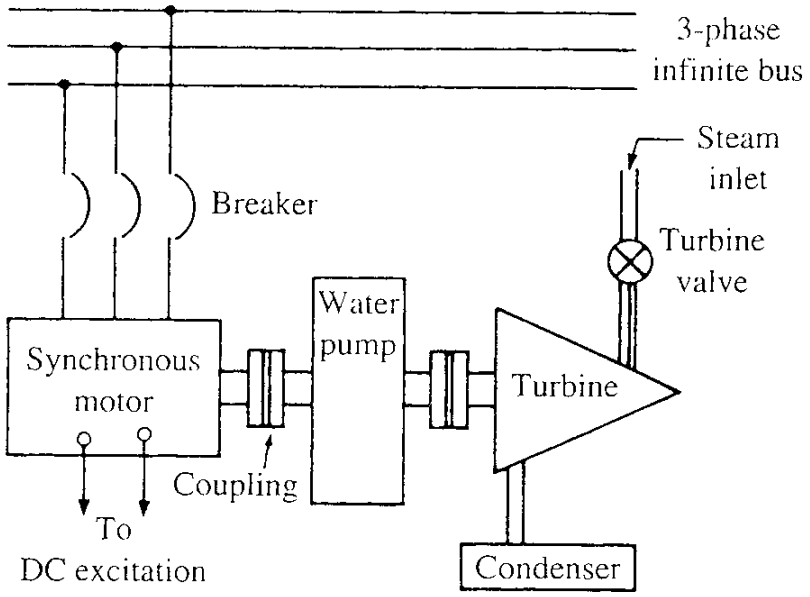


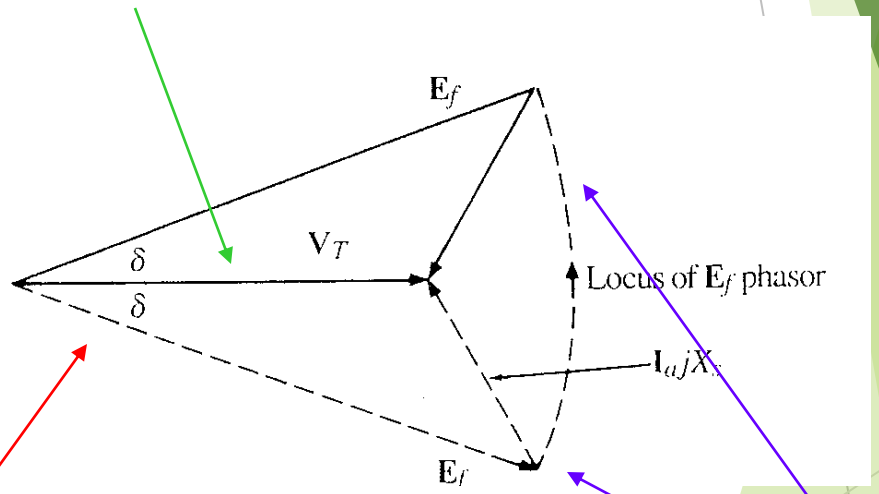


$$V_T = E_f + I_a jX_s$$

Allow the Turbine to take part load

Motor becomes a generator as δ becomes > or = zero

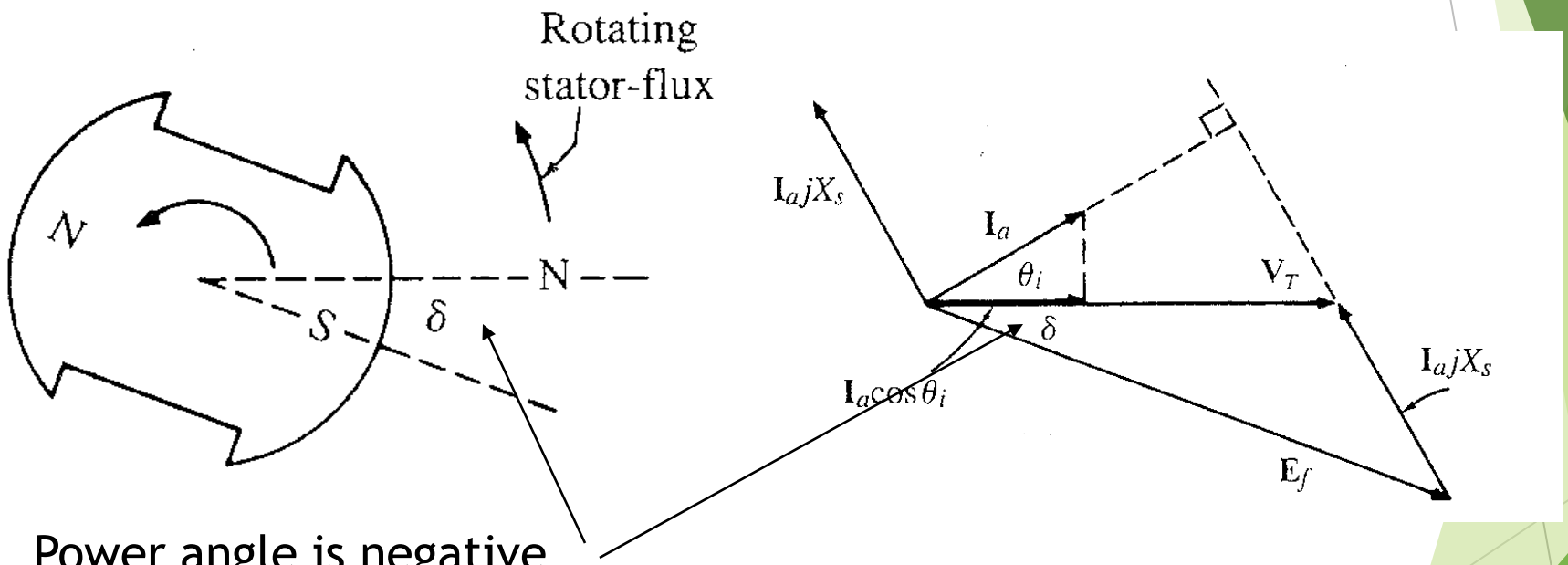




The power angle decreases to zero and then becomes positive

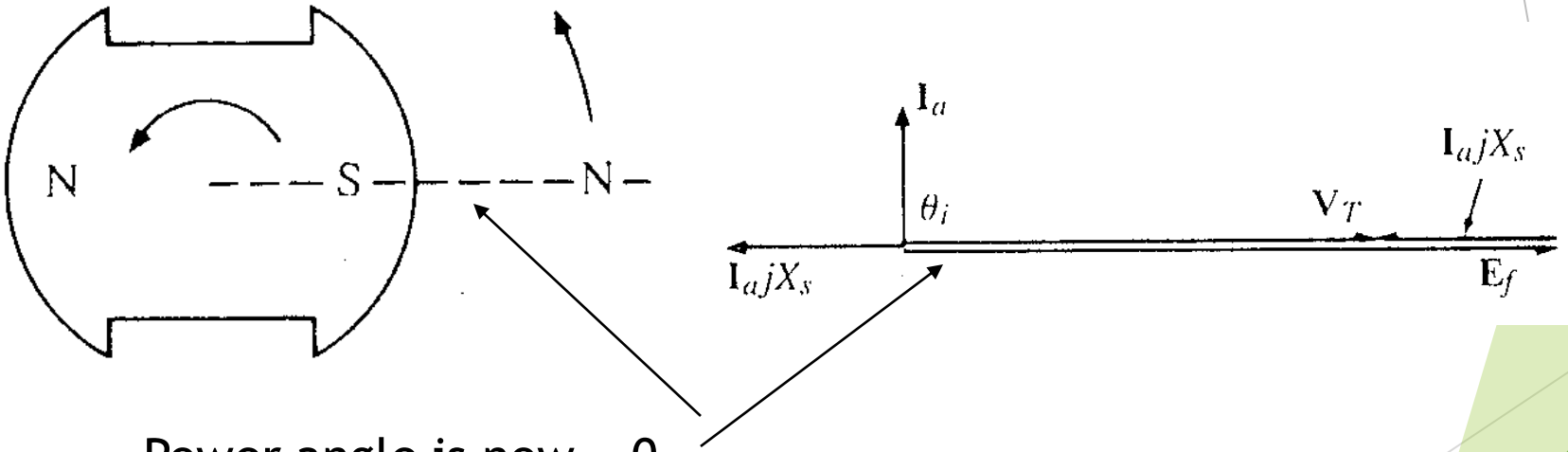
Excitation voltage is not changed and the vector traces an arc

Motor Action



Power angle is negative

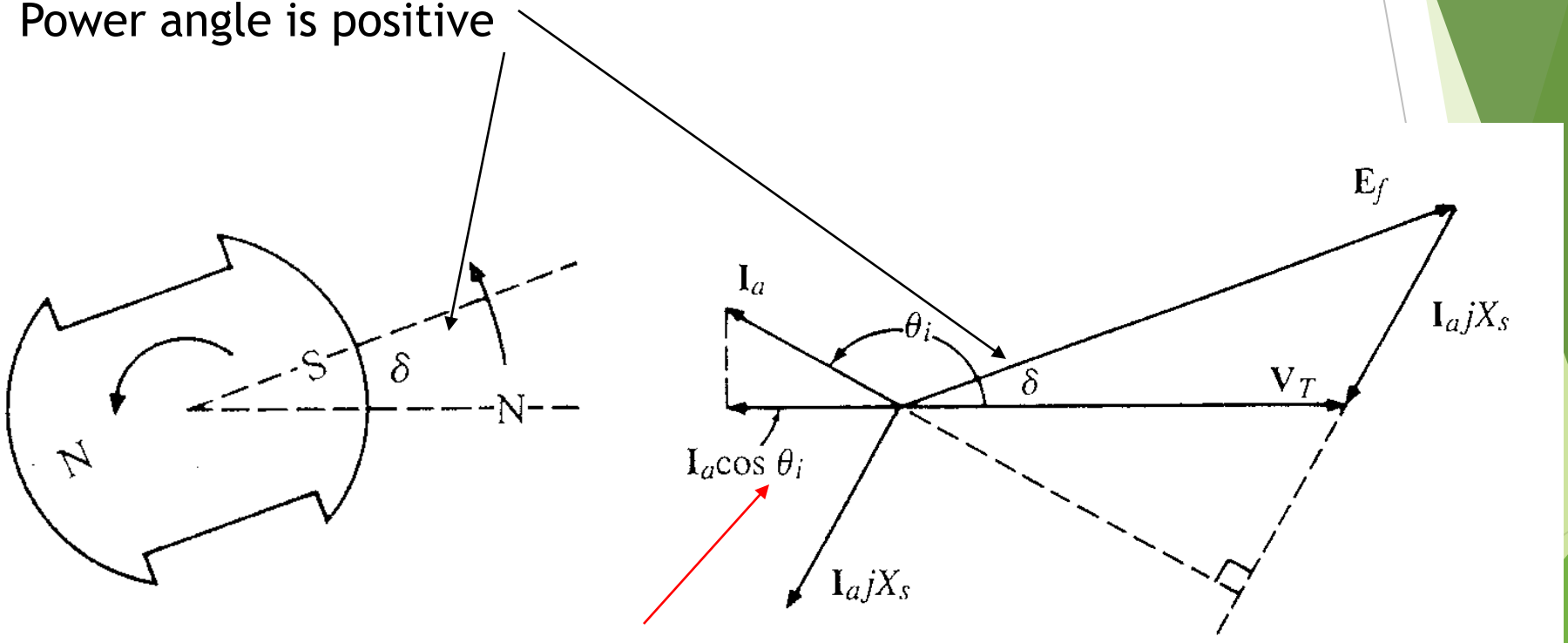
Motor to Generator Transition



Power angle is now = 0

Generator Action

Power angle is positive



Note: $I_a \cos\theta_i$ is reversed!

Generator Action (cont)

- In order for I_a to reverse direction, voltage E_f must become a source voltage
- $E_f > V_T$