Rotating Magnetic Fields

- 3 ways to generate voltage
  - rotate windings through a magnetic field (DC machines)
  - rotate magnetic field past windings (Synchronous machines)
  - make the reluctance varing with rotation of the rotor (Synchronous reluctance machines)
- armature windings: which carrys ac currents
- Synchronous machines
  - keyword: Faraday's law: Ea=dλ/dt
  - the number of coil poles is equal to the number of rotor poles
  - salient-pole vs cylindrical-rotor
    - salient
      - low speed (because it need large number of poles w=120fe/P) example: hydroelectric
      - concentrated windings
      - reluctance is sinusoidal (flux=Ni/Rm)
    - cylindrical
      - high speed (low number of poles) example: steam/ gas turbines
      - distributed windings
      - Ni is designed to be sinusoidal
- Induction machines
  - keyword: transformer action
  - IM vs SM
    - rotating speed of rotor is different
    - armature windings of IM are on the rotor, for SM on stator
    - IM are usually used as motor while SM are mostly generator
      - exceptions: 1. use SMs as motor if need high power 2. wind turbine power plant is IM
- DC machines
  - keyword: F=BILsinα
  - armature windings are on rotor- alternating voltage is rectified by commutators and brushes
  - electromagnetic torque: due to amature reaction, fixed (in space) rotor flux interacts with field flux
    - generating mode: Tem opposes rotation; motoring mode: Tem in the dirction of rotation
- MMF of concentrated windings
  - shape: rectangular
    - how to get it: Ampene's law and Guass's law (average value is 0)
  - problem: using Fourier series to get fundamental harmonic will introduce high order harmonics
- MMF of distributed windings
  - shape: stair with a flat top
    - introduce a winding factor in mmf function
  - advantage: minimize high order harmonics
    - in rotor windings, the number of turns per slot is independent from other slots, so they are varied to control high order harmonics
  - for DC machines
    - shape: sawtooth waveform (without flat tops)
    - current density is rectangular waveform
- MMF of a single-phase winding on stator
  - shape: fixed in space but its amplitude varies sinusoidally in time
    - fixed in space: winding function
    - varied amplitude: ia=coswt
  - it can be divided into a positive travelling wave and a negative travelling wave
    - problem: negative wave introduces negative torque and losses
- MMF of stator windings of 3-phase machines
  - shape: rotates at synchronous speed with a constant amplitude 3*1/2 MMFmax
  - the sum of negative travelling waves of 3 phases is 0
- Calculate induced voltage
  - flux phi-flux linkage λ-Farady's law
  - Lss, Lsr, Lrr, λs, λr, transformer voltage, speed voltage
    - when the airgap is uniform, Lss and Lrr are constant
      - Torque results only from mutual inductance
      - For three phase case, if the rotor speed is sychronous, torque is constant, depending on torque angle δ
    - when the rotor is salient, Lss also depends on the rotor position
- Calculate torque
  - T= - f(ploes,1/g)*Fs*Fr*sinδsr
    - EM torque is proportional to the peak values of the stator- and rotor-mmf and to the electrical space-phase angle δsr
  - if Fs is perpendicular to Fr, one can produce maximum Tem
  - when Fr leads Fs (δsr>0), Tem <0, generating mode