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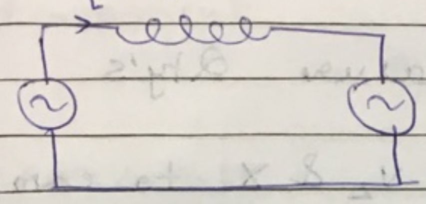
→ Can we get upf current using sine PWM?

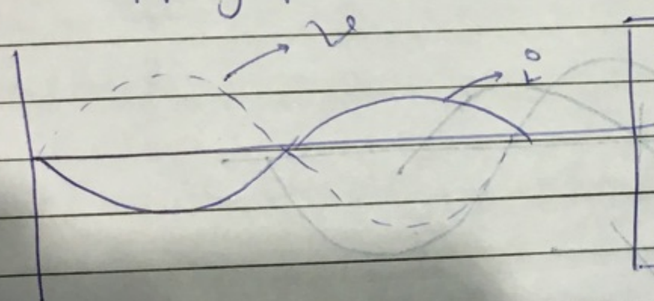


- Sine PWM: Indirect

We are generating the voltage waveform which forces the ~~sine~~ current.

- HB PWM: Direct

→ To supply power to DC source



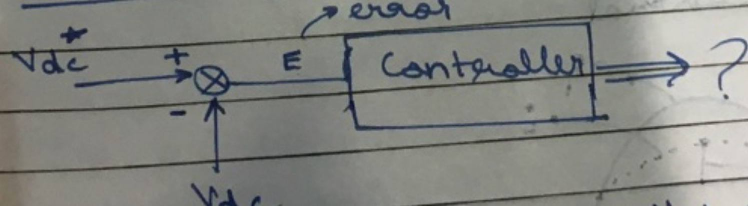
→ Achieve upf

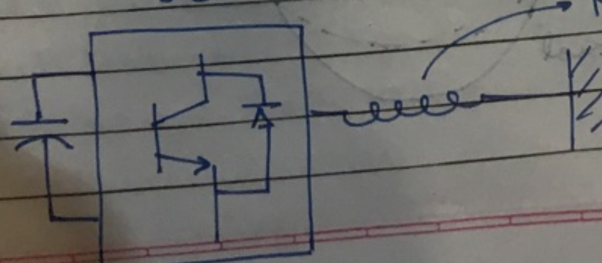
AC → DC conversion

→ Choose δ such that in the Inphase comp. of current, there is power balance.

23.3.17

Quiz-2 Question





→ Not required when feeding IM, Leakage limits current.

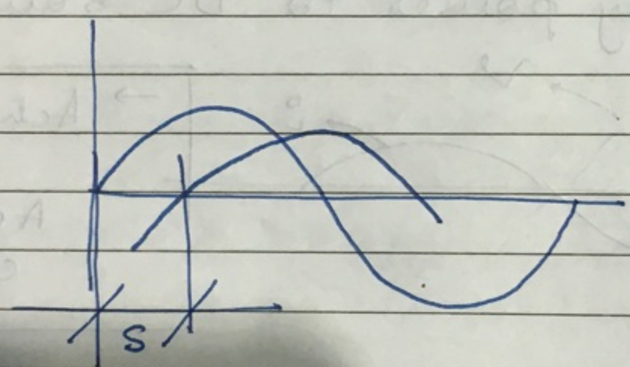
$$? = \frac{V_1 V_2}{X} \sin \delta$$

→ Not possible to measure Qty's

- Can't measure V_1, V_2 & X to compute δ.
Recorded Information not used.

V_{dc}^{*} → Desired (say 600V) (Reference)
V_{dc} → Actual : say 590V (Cap. Voltage)

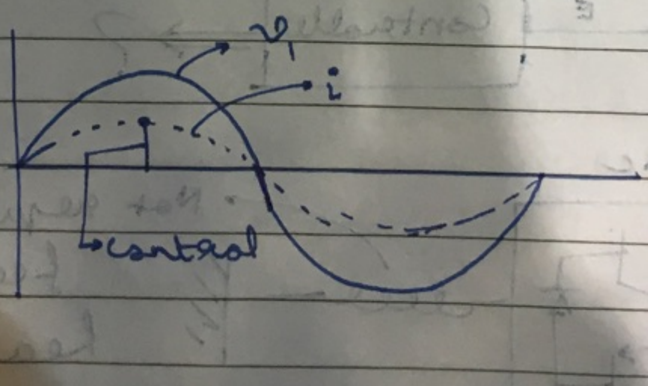
→ Cap. Voltage is falling



→ Supplying power to cap. must ↓

Voltage control → δ

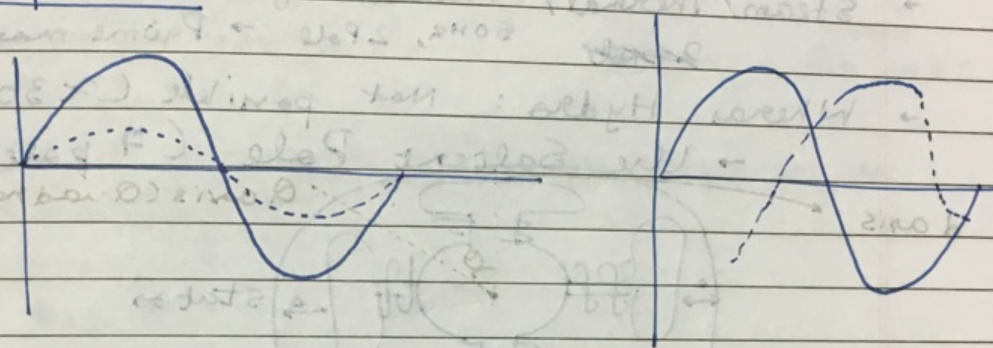
→ Current Control



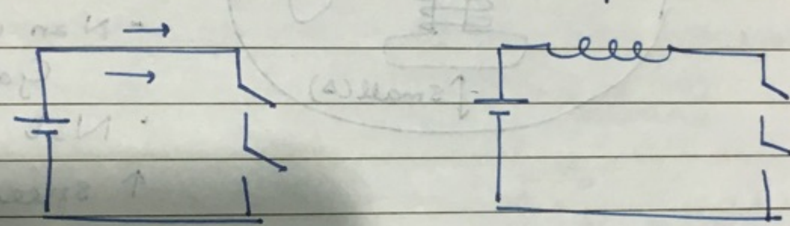
→ Non upf ($\delta = 90°$ say.) $\Rightarrow P = 0$.
Must find in phase component and quadrature component.

$\Rightarrow \cancel{\dfrac{N_1 V_2 \sin\delta}{X}}$

2 components



Q-4)



Synchronous Machine

- Used in ALL generators.
- Speed is independant of load. $\dfrac{120F}{P}$
- Usually MW range

Stator	Rotor
AC	DC → Mostly
DC	AC → Rare (Why?)

(Rotor → Find out why?)

- In IM pf is always lagging. since I_M must be supplied
- Brushless DC Motor is a synchronous machine (PM Synch. Machine)

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Syn. Generator

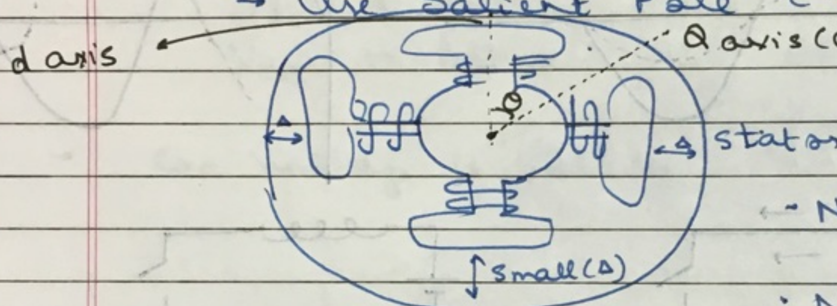
- Stator → 3 ɸ Sine. distributed winding
- Rotor → DC I
  - → 2P Cylindrical

→ Steam/Thermal/Nuclear Gen. are 2 pole

~~2 pole~~ 50Hz, 2Pole → Prime mover 3000 rpm

→ Wheras Hydro : Not possible (≈300 rpm)

→ Use Salient Pole (4 pole const.)



- Non unifor Air Gap.
- Not suitable for ↑ speed (Air resis?)

Field Axes

→ d axis (Small Air Gap)

→ Q axis (Larger Air Gap)

→ $\mathcal{R}_d << \mathcal{R}_Q \Rightarrow X_d >> X_Q$

Equivalent Ckt

→ I_F in Rotor winding, producing flux,

Assume $N_s = 3000$ rpm (2pole)

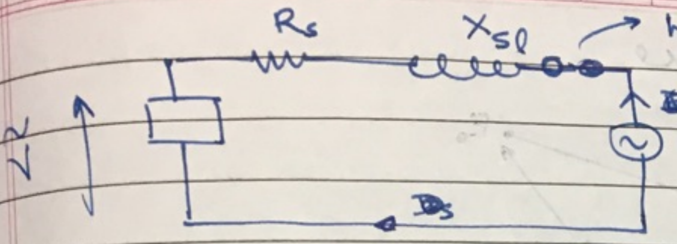
↪ ϕ_{DC} 3000 rpm

→ Stator (AC winding) voltage Induced

~~RMS value $\propto 4.44 \times F \times \phi_{DC}$~~

RMS value $\propto \omega I_F$

(Also number of turns in stator, can't change)

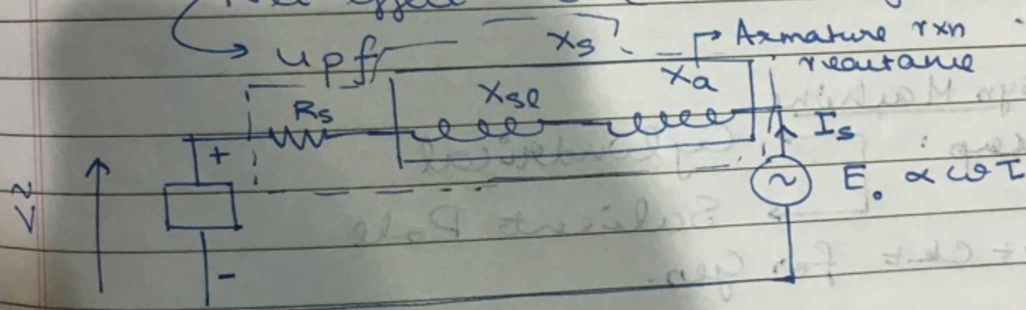


→ What else

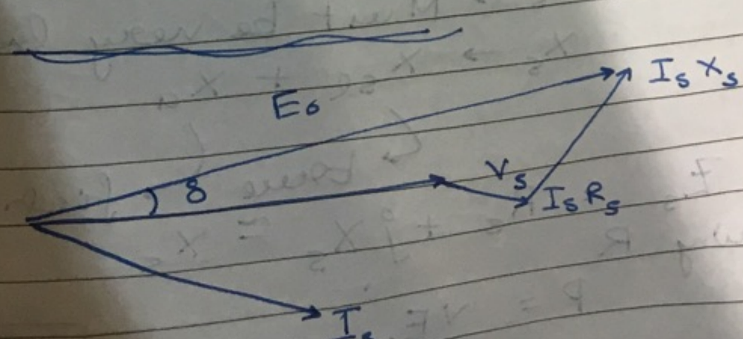
$E_o \propto \omega I_F$ (Due to field flux alone)
↓
was E_b in DC

→ In DC Machine, there was Arm. Rxn. (Current flows in S, has its own field)

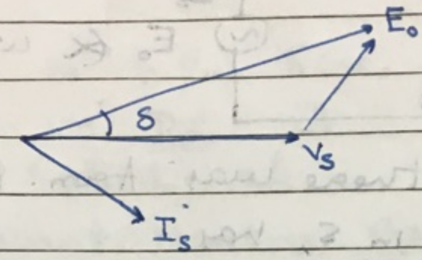
→ Current flowing could aid / oppose or do nothing
→ Aid
→ Oppose
→ Net effect = 0 (Cross Magnetization)
↳ upf



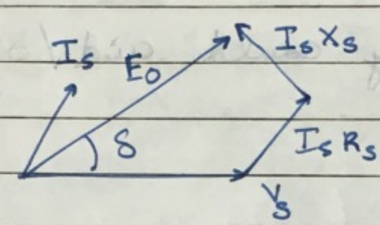
X_a → Not a real reactance
X_s → Synchronous reactance
Z_s → $R_s + jX_s$ (Syn. Impedance)



→ Ignore resistance



→ Leading Current

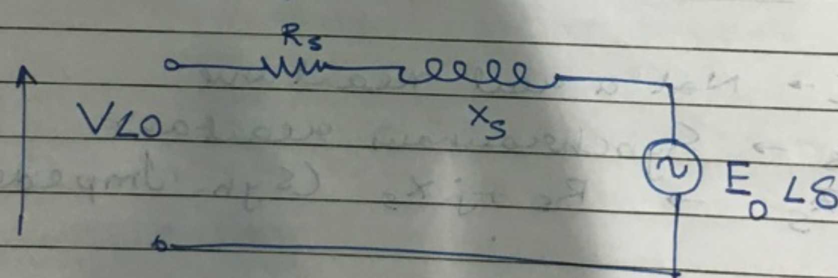


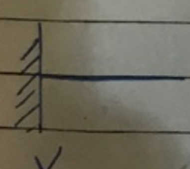
28.3.18

Syn Machine

Recap: → Cylindrical
→ Salient Pole

Eqvt ckt for Gen.





R_s → Must be very low

$X_s \rightarrow \underbrace{X_{sl}}_{\text{true}} + \underbrace{X_a}_{\text{fiction}}$

$$Z_s = R_s + jX_s \simeq X_s$$

→ Ignoring R

$$P = \frac{VE_0}{X_s}\sin\delta \, , \quad \boxed{Q = ?}$$

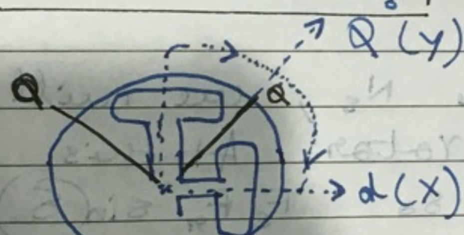
→ Infinite Grid : V, f are fixed

1) M/C Connected to the grid → V, F = K

→ Power output cannot change unless there is change input.

→ Hence on change in excitation : Active component cannot change ⇒ Reactive comp. changes ⇒ P.F ↗

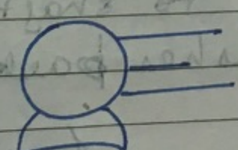
H.W : $\boxed{\text{Derive : } P = ?}$ for salient pole.



$\boxed{X_d >> X_q}$

less Magnetizing current required

→ Synchronous Motor



Self Start?

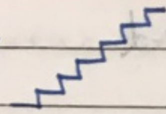
→ $T \propto F_s F_r \sin\delta$

F_s & F_r should be stationary (steady state)

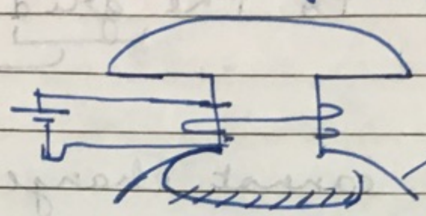
$F_s \to \frac{120F}{P}$, $F_r \to 0$ at start

→ Speed of F_r = Speed of Rotor

→ If freq. (at start) is small then rotor may catch up (Depends on Inertia)

F  → Rotor may catch up ⇒ $N_r \uparrow$

Winding Solution



→ Rotor has both $\underbrace{\text{cage Rotor}}_{\text{starts}}$ & $\underbrace{\text{DC type.}}_{\text{at syn. speed.}}$

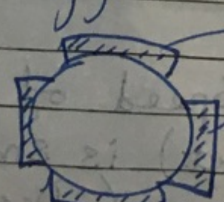
→ Before synch. speed, cage Rotor gives torque like IM

→ Just before N_s, we will close DC source to rotor. At this $N_r < N_s$ (slightly) so $F_s F_r \sin \delta$ → not constant

→ Pulsations will push Rotor to N_s

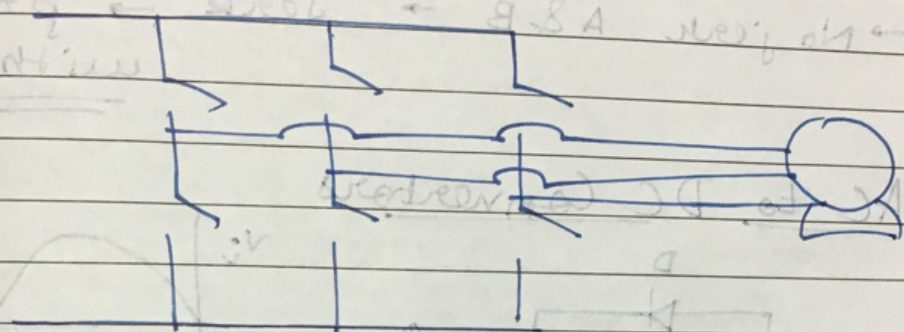
• If we add load to shaft, again $N_r < N_s$ & Cage pushes back to δ (N_s)

• Permanent Magnet (Unstable ~~since~~ for certain loads: Sudden Impact loads) OK for fan & pump since T_L cannot change instantly (∵ we cannot change instantaneously)



→ Address ~~con~~ unstability using control systems. (What happens on sudden loading)

PMSM - (Per. Mag. SM)

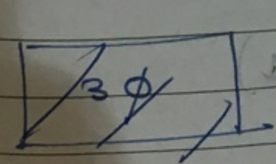


→ Stator unaffected by any such external event.

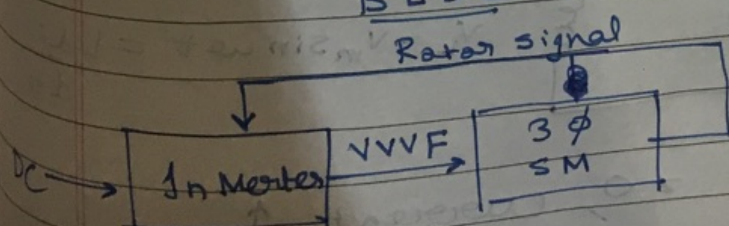
→ Rotor speed determined by stator frequency

Instead: Generate stator frequency as a function of rotor speed. (Make it dependant)

→ No longer a constant speed/synchronous machine. (Similar to DC machine)
But no brushes ⇒ Brushless DC motor



BLDC ~~(Brush~~



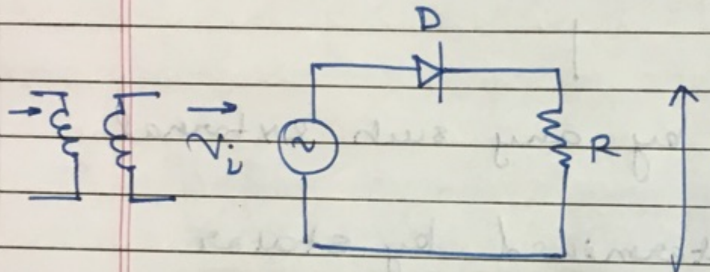
3φ SM has per. magnets & its synch. speed depends on rotor speed.

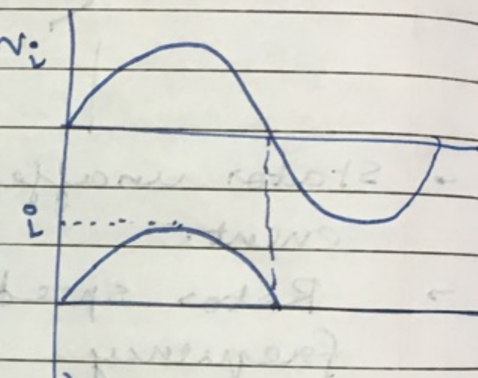
Have → Read!

Starting BLDC

- → Stator phase ABC (like F control)
  Excite A ~~with~~, Jerk? → proceed
  → No jerk A & B → Jerk → proceed with F ↑ AB, BC →

AC to DC Converters





$\alpha \to 0$ (conduction starts)
$\beta = \pi$ (conduction stops)

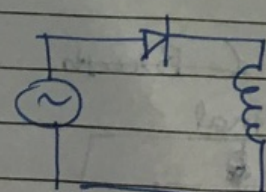
$\gamma = \beta - \alpha =$ Conduction period, on time

$$\boxed{V_o = \frac{V_i}{\pi}}$$

→ DC/Average value.

- → $R \to L$ (Purely Inductive load)

$\alpha = 0$
$\beta = 2\pi$



$V_L = V_m \sin \omega t = L\frac{di}{dt}$

$\alpha > 0 \to L\frac{di}{dt} > 0$, current ↑

$\alpha = \pi \to L\frac{di}{dt} = 0 \Rightarrow$ Current $= i_m$

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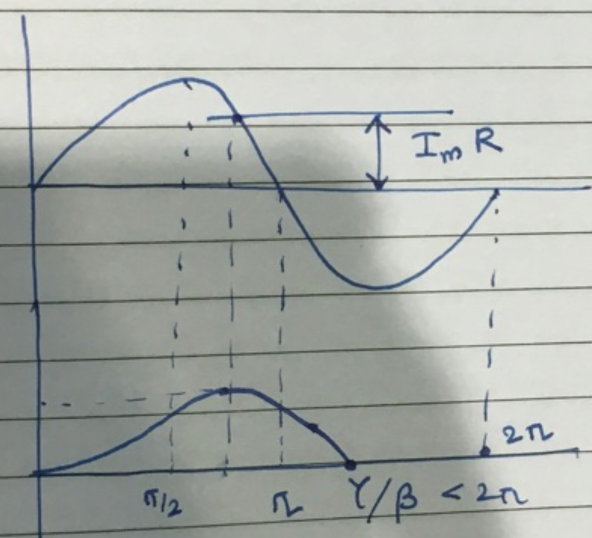
$2\pi > \alpha > \pi \rightarrow L\frac{di}{dt} < 0 \Rightarrow$ current decreases from i_m

$\Rightarrow$ v_o is sine, but i_o is not (unidirectional)

$\rightarrow$ (R+L) type load.

$$Ri + L\frac{di}{dt} = v_m \sin \omega t$$



$\rightarrow$ As $\gamma \uparrow$, average value of $v_o \downarrow$ (Counter Intuitive)

Reason: Beyond π, v_i is < 0

Quiz-4 soln.

A-1) 2m + 2m

1m → Ans
1m → Just.

A-2) Must show subtraction of two sines.

A-3) ✓ fourier transform

A-4) Table: 1m (All 4 Ans) (0.25×4)
1m (All Just) (0.25×4)