On-Load starting.

(i) Damper Winding starting. (amortisseur)

- To make synchronous motor self-starting, damper windings are placed in rotor pole faces.
- Damper windings are made up of thick copper wires or copper bars.
- These damper windings are shorted at both the ends using metal rings.
- So, the arrangement of damper windings is similar to squirrel cage windings of a 3-phase induction motor.
- Initially, 3-phase ac supply is given to stator winding, which produces a rotating magnetic field.
- Rotor is not energised initially. So, the rotating magnetic field cuts damper windings, which act as squirrel cage. So, the motor starts rotating as squirrel cage induction motor.
- When the speed of rotor reaches near synchronous speed, the rotor is given DC supply.
- The rotor is pulled into synchronism and stator and rotor field gets magnetically inter-locked, producing a stable unidirectional torque.

(ii) Variable voltage and frequency starting – (Keeping $\frac{V}{f}$ = Constant)

- With advances in power electronics, variable frequency supply can be easily obtained.
- This method is used to start the synchronous motor on load.
- Initially, both voltage and frequency is kept low, keeping $\frac{V}{f}$ ratio constant to avoid saturation of machine core.
- So, after giving low voltage and low frequency supply to the stator, rotor is given DC supply.
- Since, input frequency of stator supply is very low, so, rotating magnetic field also rotates slowly and rotor is able to catch up with this rotating magnetic field.
- Once stator and rotor fields are magnetically inter-locked at low frequency, we can now increase voltage and

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frequency to its rated ~~voltage~~ value, keeping $\frac{V}{f}$ constant.

Armature Reaction in Synchronous Motors.

In synchronous generator

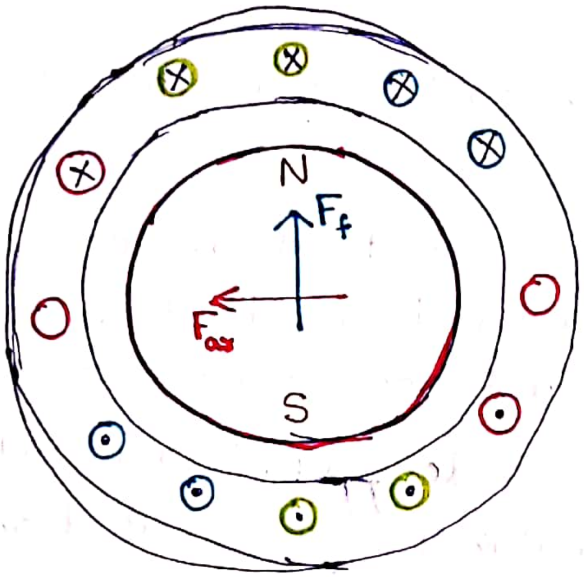
- When we talk about power factor, it is that of the alternator itself.
- When we are seeing the effect of armature reaction, we take the current to be leading, lagging or at unity p.f. and accordingly see if effect is magnetising or de-magnetising and accordingly whether alternator is over-excited or under-excited.
- But, in actual, we adjust the excitation of the machine first and accordingly the machine works on leading or lagging power factor.

In synchronous motor

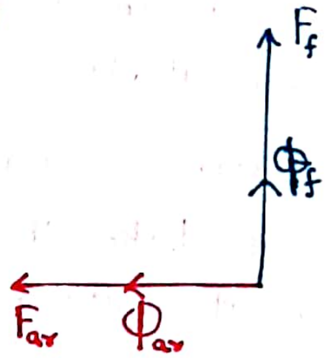
- Here also, the power factor we are talking about is that of the motor itself; i.e. whether motor is working on lagging or leading p.f.
- While analysing effect of A.R., we take current to be leading or lagging first and see if motor is under-excited or over-excited.
- But, in actual, we adjust the excitation of the motor first and accordingly see if machine is working on leading or lagging power factor.

Armature Reaction in Synchronous Motor

(i) Unity power factor

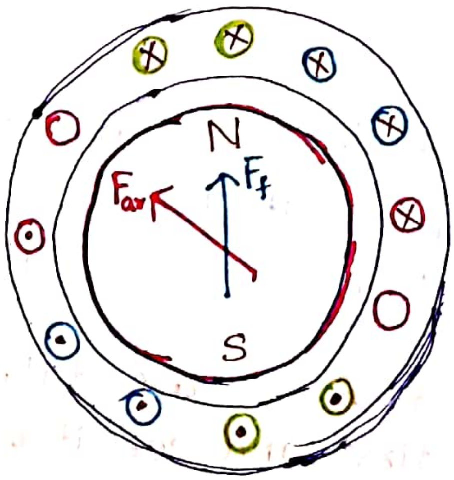


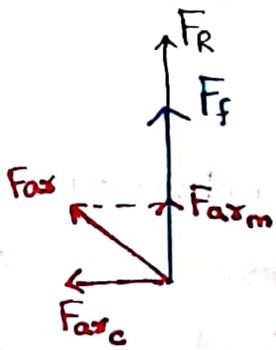
Cylindrical rotor synchronous motor at unity p.f.



∴ Effect of armature reaction at unity p.f. is cross-magnetising.

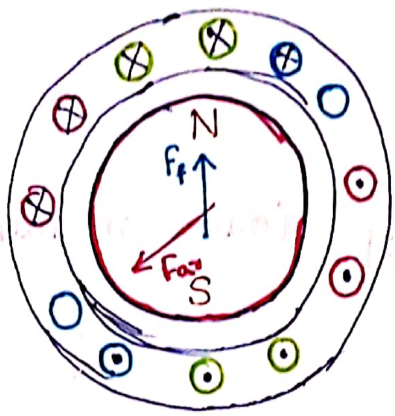
(ii) lagging p.f.

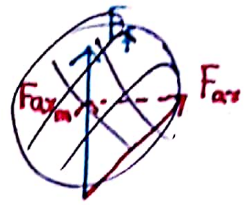


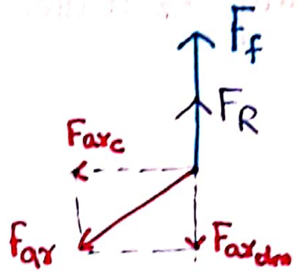


- So, at any lagging power factor, armature reaction is both magnetising and cross-magnetising.
- Motor is under-excited.

(iii) Leading p.f.

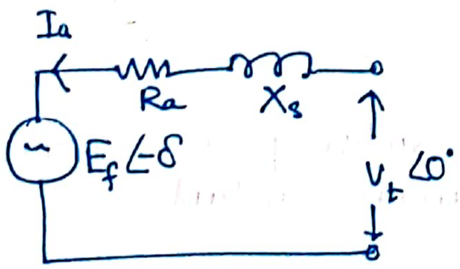




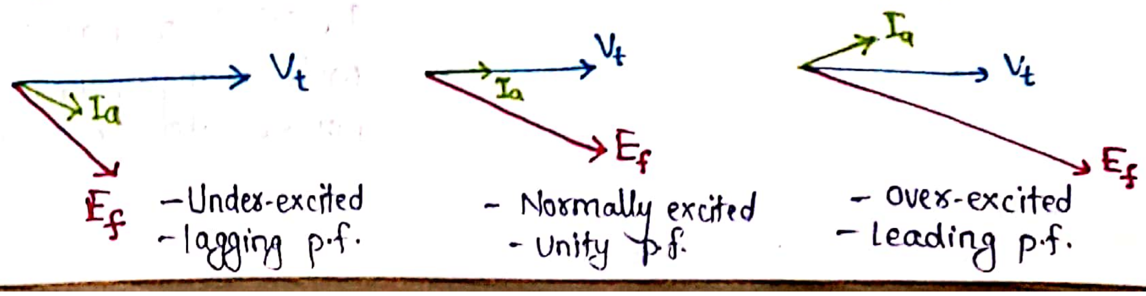


- So, effect of armature reaction is both cross-magnetising and de-magnetising.
- Motor is over-excited

Equivalent circuit and phasor diagram.



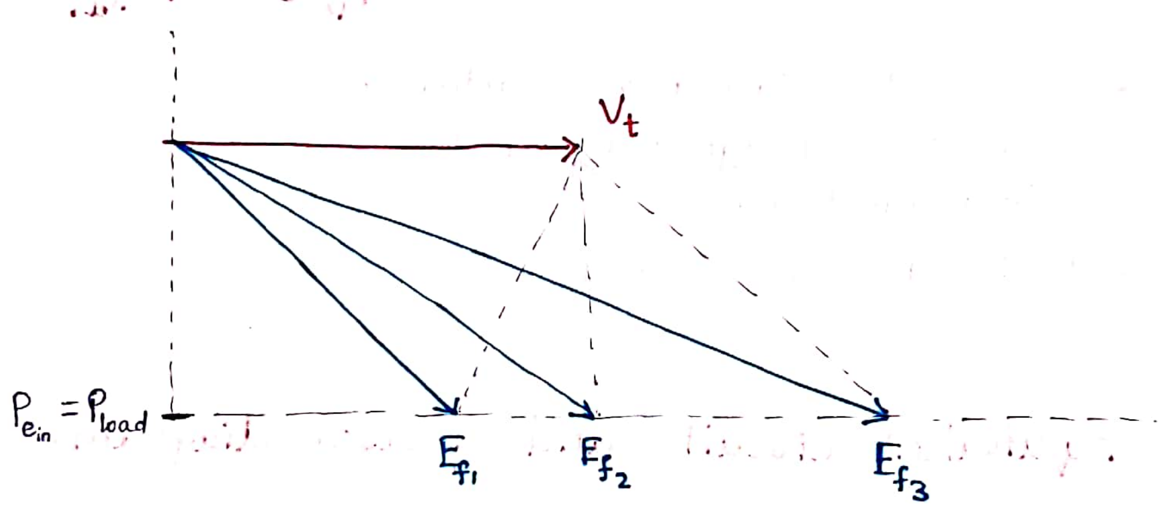
- Active power flows from Leading angle to lagging angle. So, if we keep V_t as reference, at 0°, then E_f will be at $-\delta$, for the machine to act as synchronous motor and consume active power.



Effect of varying field current at different loads.

(a) Excitation curve.

(i) – Varying excitation keeping Load constant.



- Load is constant ⇒ So, active power consumed will remain constant
- With changing excitation ⇒ Only reactive power taken or delivered by motor changes.
  - ⇒ Armature current I_a, changes but that is because of changing reactive power. $I_a \cos\phi$ remains constant with changing I_a, so active power taken remains constant.

$$P_{in} = \frac{V_t \cdot E_f}{X_s} \sin\delta$$

V_t = constant

X_s = Constant

P_{in} = Constant.

$\therefore$ $E_f \sin\delta$ = Constant.

→ So, with change in excitation, but load remaining constant, $E_f \sin\delta$ remains constant.

→ Only $E\cos\delta$ changes, depending on which the reactive power taken or delivered by the synchronous motor changes.

Similarly,

$$P_{in} = V_t \cdot I_a \cos\phi$$

P_{in} → constant

V_t → Constant.

So, $I_a \cos\phi$ = constant.

→ So, with changing excitation keeping load constant, I_a changes. but $I_a \cos\phi$ remains constant.

→ I_a changes to meet the reactive power requirement.