Chapter 9 Single-phase and Special Motors

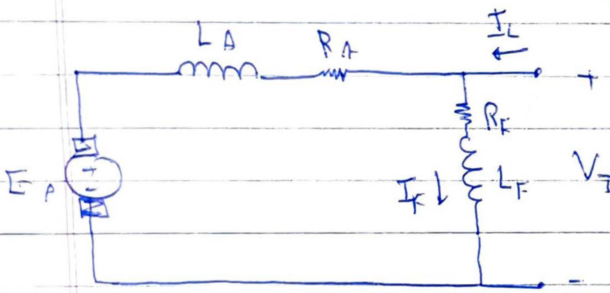
ⓐ Types of 1-φ & special motors:

1) Universal motors
2) 1-φ induction motors] only
3) Reluctance motors
4) Hysteresis motors
5) stepper motors
6) brushless DC motors

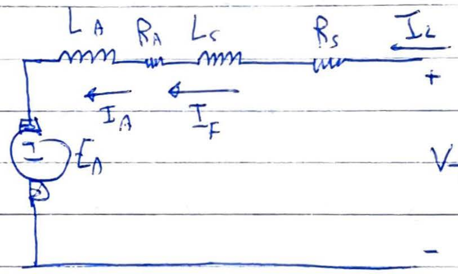
10 cos
$\int$ (10 sin(φ))

① Universal motors: (low power Application)

هو شغل Dc موتور
بتغذيه Ac فولت



shunt excited



series excited.

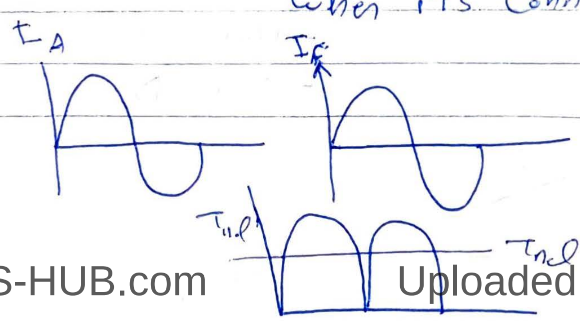
Induced Torque ⟹ $T_{ind} = K\phi I_A = Kc\, I_F I_A$

If $V_T > 0 \Rightarrow I_A > 0$ & $I_F > 0 \Rightarrow T_{ind} > 0$

if $V_T < 0 \Rightarrow I_A < 0$ & $I_F < 0 \Rightarrow T_{ind} > 0$

الفكرة انه عند دمج الـAc بالـ
بعطي اكثر الدوائر عكس
في Dc circuit .

Polarity is Reversed ⟹ Its possible to get a positive pulsating Torque from the DC motor (series or shunt) when its connected to AC supply



[1]

For shunt DC motors ⇒ L_F is very high ⇒ I_F is reversed slowly ⇒ $T_{ind,avg}$ decreases

⇒ Therefore, the universal motor is implemented using the series DC motor since I_A & I_F are reversed at the same time

Define: A universal motor: is basically a series DC motor with its core laminated run from AC supply.
(To reduce the core losses)

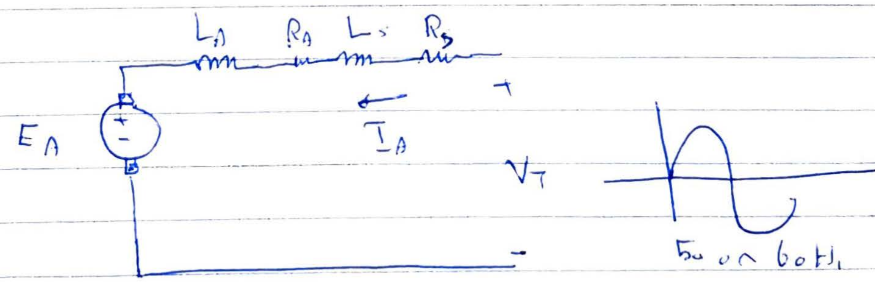
ويكون فيه eddy current من AC res
عكس الـ DC لأنه eddy current ما في
لذا core laminated

* Its called universal because it can be run from either AC or DC supply

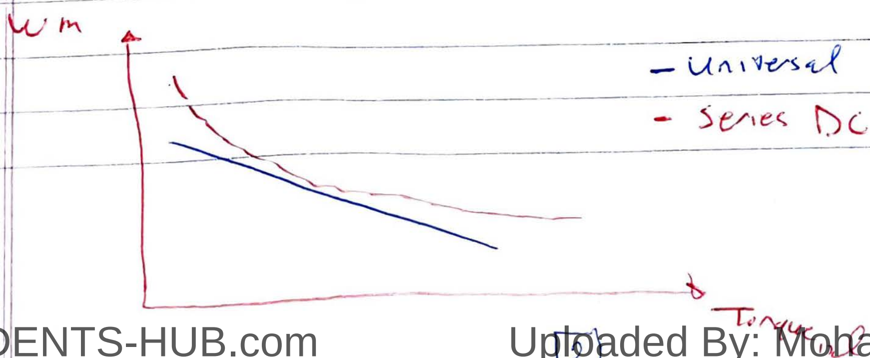
(the same eq circuit).

* Universal motor: its a series DC motor with its core La--

equivalent circuit:

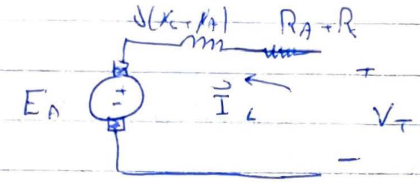


Torque speed curves:



The Torque speed curve for universal motors differ from the Torque speed curve of series DC motors for Two Reasons :

1) The voltage Drop accross the armature & field inductance

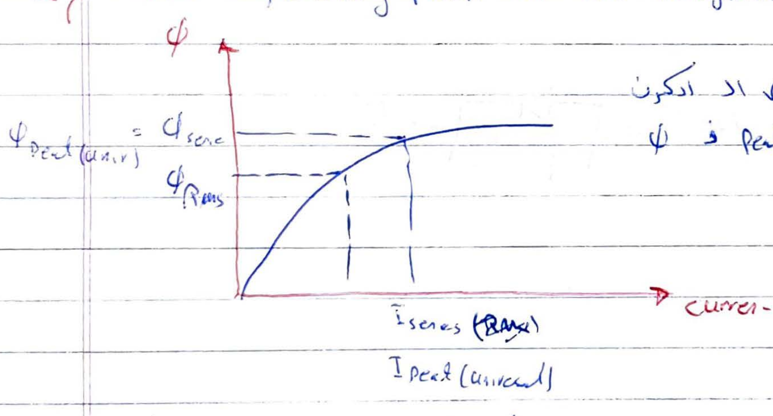


$$\vec{E}_{A_{univer}} = \vec{V}_T - \left((R_A+R_S) + j(X_S+X_A)\right)\vec{I}_L$$

$$< E_{A_{series}} = V_T - (R_A+R)\vec{I}_L$$

so $E_{A_{universal}} < E_{A_{series}} \Rightarrow \omega_{m_{uni}} < \omega_{m_{series}}$ for the same flux & current levels.

2) The operating point on the magnetizing curve.



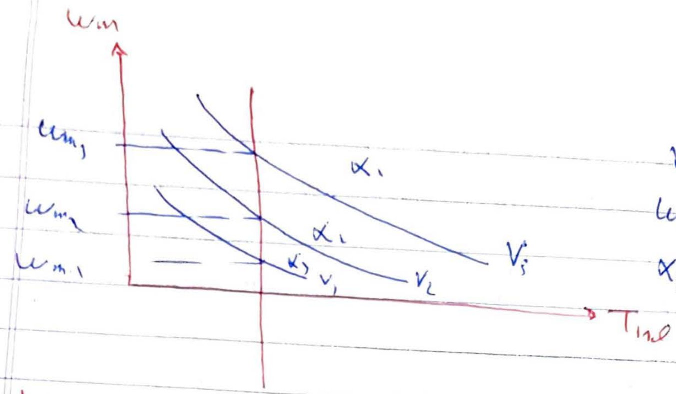
وذلك في ϕ بتعامل مع RMS بدل ال ادكرت
بأخذ Peak بدل RMS لأنه peak في ϕ
بقل بالتالي Torque ↓

The peak value of the line voltage is $\sqrt{2}$ times the RMS value → This means the knee point or operating point on the magnetizing curve must be peak quantities to avoid saturation $\Rightarrow \phi_{RMS}$ will be lower $\Rightarrow T_{ind,universal}$ will be also lower for the same current level.

Applications → Vaccum cleaner, Drilles, Mixers, ---. [low power & high starting Torque]

⊛ speed Control of universal motor

1) The speed is controlled by changing the voltage applied to the motor

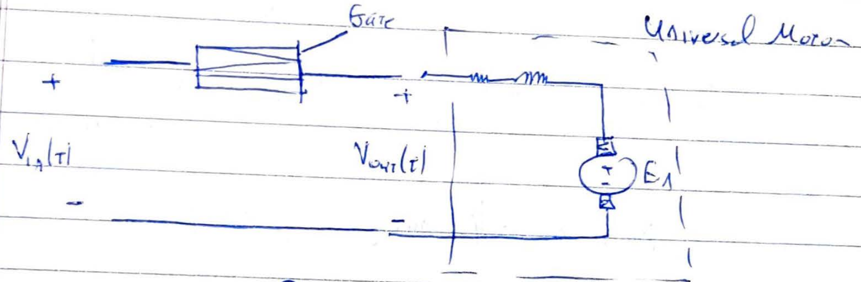


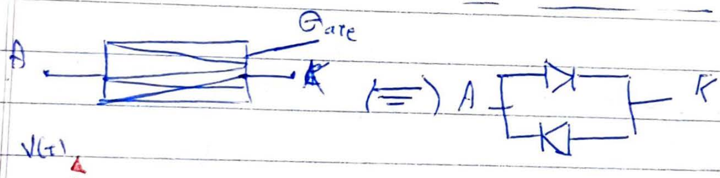
$V_1 < V_2 < V_3$

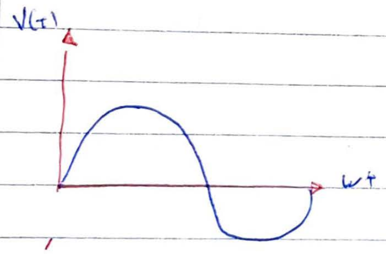
$\omega_{m_3} > \omega_{m_2} > \omega_{m_1}$

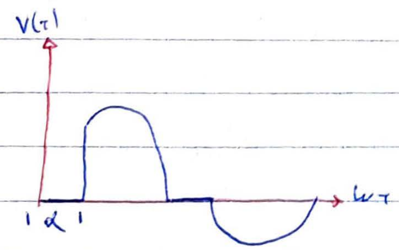
$\alpha_3 > \alpha_2 < \alpha_1$

Note: The motor's voltage is adjusted using 1-ϕ AC voltage regulator and Auto-Transformer.









كلما زادت α RMS نزلت.

$0 \le V_{out,RMS} \le V_{in,RMS}$

The RMS value of V_{out} is a function of α

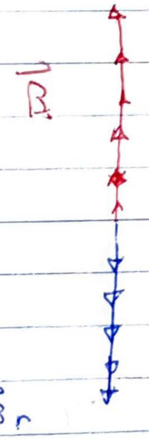
α : Firing angle $0 \le \alpha \le 180$

Single-phase Induction Motors.

Construction: The Rotor is a squirrel cage type and the stator has a single phase main winding which is supplied from a 1-ϕ Ac source.

Operation: A 1-ϕ Ac voltage is applied to stator windings to cause current to flow through the stator winding.

* The current produces a magnetic field $\vec{B_s}$, which is pulsating and Doesn't rotate.
* The stator magnetic field induces a voltage accross the Rotor bar by transformer action ($e_{ind} \propto \frac{dB_s}{dt}$)
* The induced voltage will cause a current to flows through the rotor (I_r)
* I_r produces a Rotor magnetic field B_r, which opposing $\vec{B_s}$ according to "lenz law"

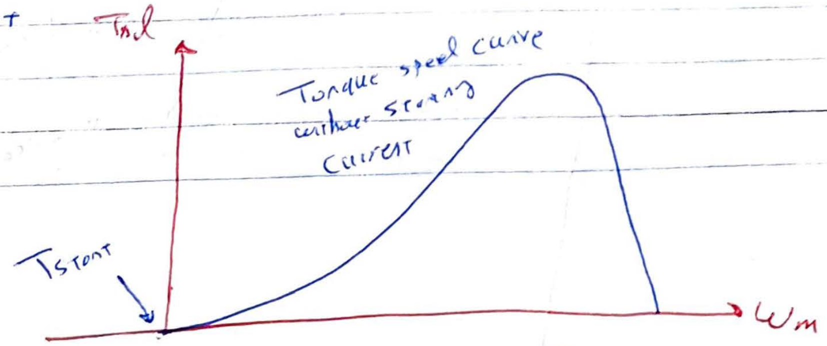


$T_{ind,start} = K \vec{B_r} \times B_s = 0$

No starting Torque in the machine

يجب تحريك الموتور مبدئياً

Once the motor starts to rotate, the Torque is induced on it



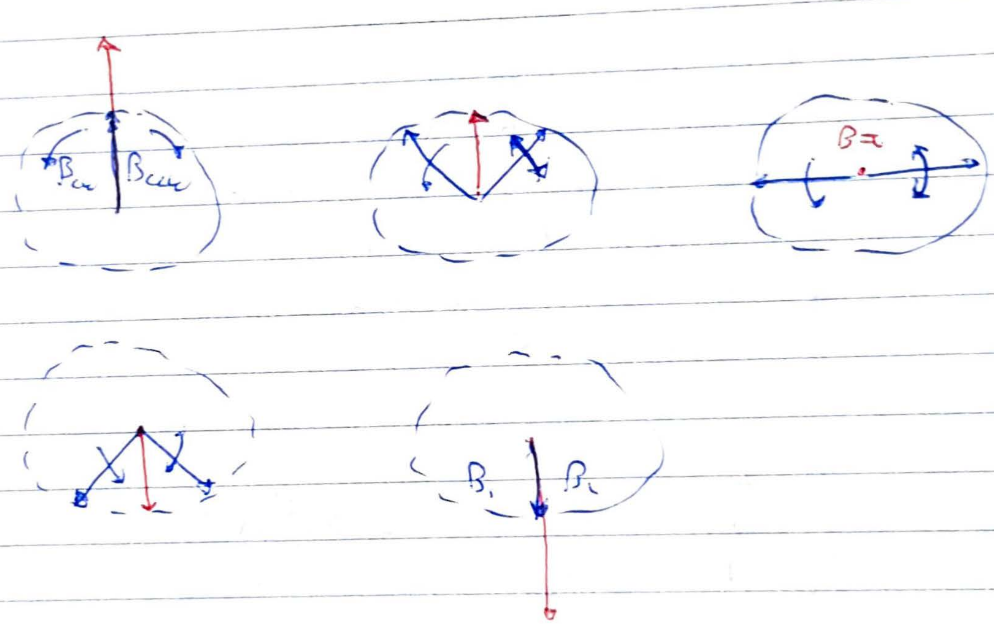
مهم جداً ال
equivalent circuit

Double Revolving Field Theory

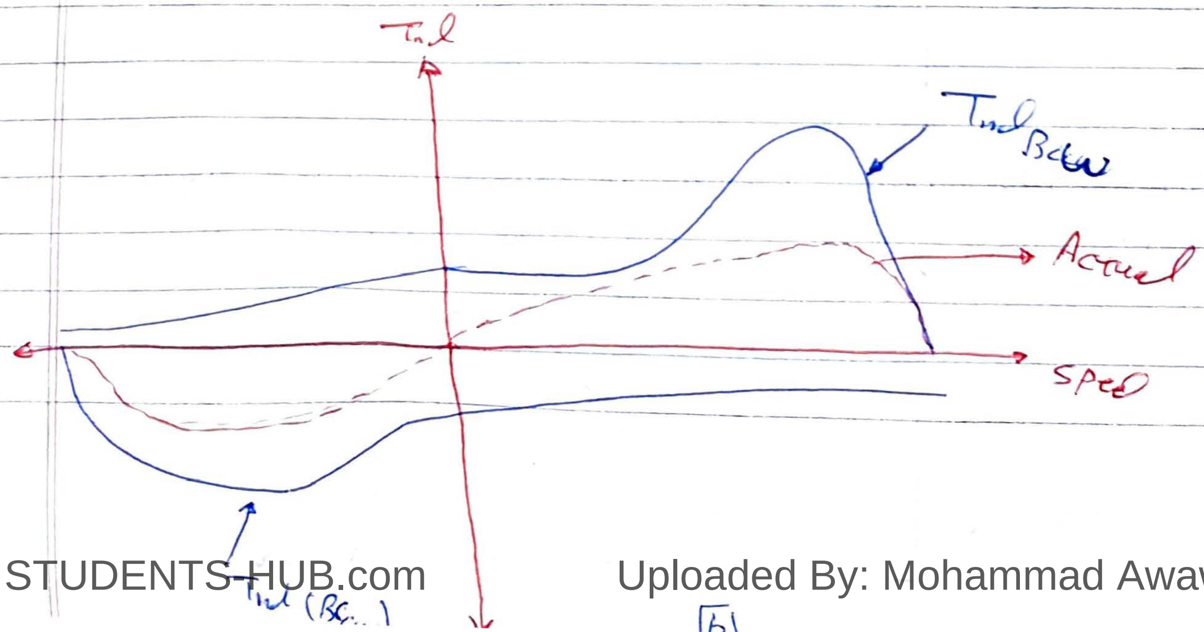
The stator magnetic field is resolved into two magnetic field that have the same magnitude & rotate in opposite direction

$\vec{B}_s$: stator magnetic field
$\vec{B}_{cw}$: clockwise rotating magnetic field
$\vec{B}_{ccw}$: counter clockwise rotating magnetic field

$$\vec{B}_s = \vec{B}_{cw} + \vec{B}_{ccw}$$



$$T_{ind} = T_{ind}\Big|_{B_{ccw}} + T_{ind}\Big|_{B_{cw}}$$

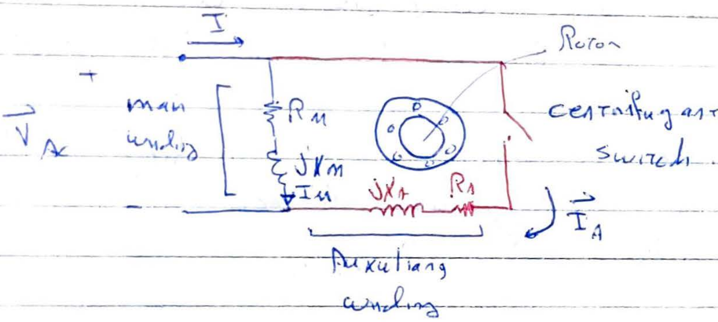


Starting techniques of 1-φ induction motors

Starting method

- split-phase
- capacitor type
  - capacitor start
  - capacitor start and run motor
  - capacitor start & capacitor run
- shaded pole

① split-phase 1-φ IM



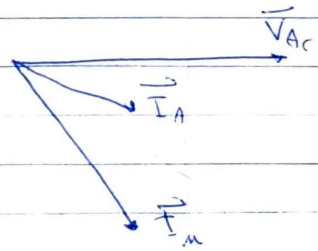
Auxiliary winding is designed such that $\vec{I_A}$ leads $\vec{I_M}$ by some angle (30°–45°)

Assume

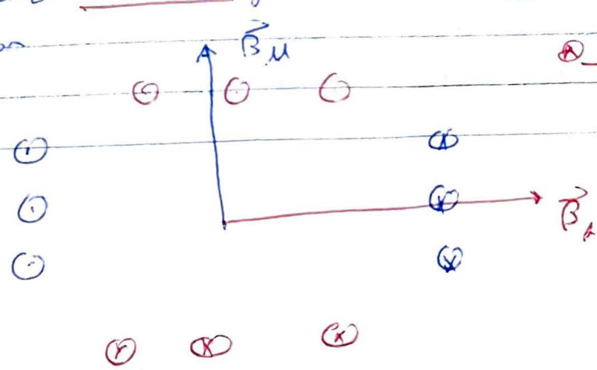
$V_{AC} = V_m \sin(\omega t)$

$i_A = I_A \sin(\omega t - \theta_{i_A})$

$i_m = I_M \sin(\omega t - \theta_{i_m})$



The auxiliary and main winding are set at 90° electrically apart along the stator



Two stator field

الملفات كيف ابو ركبتوا
متعامدات ودا لا يكفي

7

The flux densities $\vec{B}_A$ & $\vec{B}_M$ are given by ...

$$\vec{B}_A = B_A \sin(\omega t - \theta_{iA}) \angle 0^\circ$$

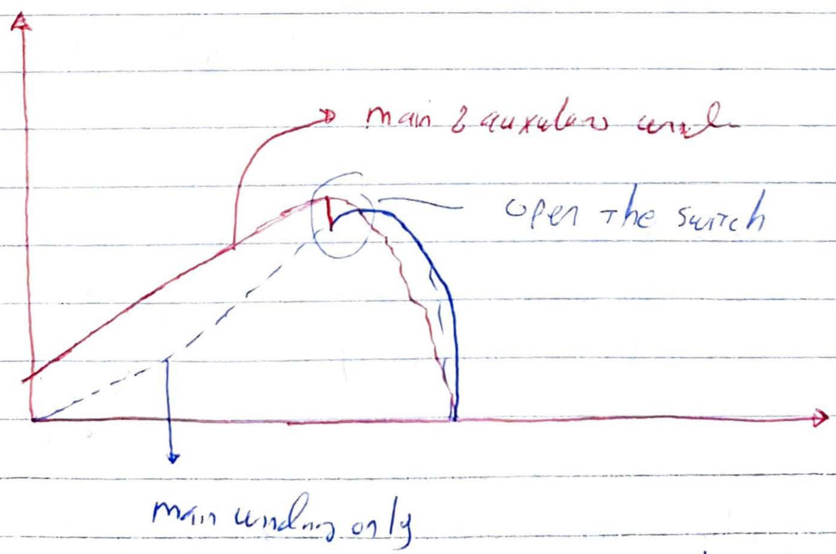
$$\vec{B}_M = B_M \sin(\omega t - \theta_{iM}) \angle 90^\circ$$

Since $\vec{I}_A$ lead $\vec{I}_M \Rightarrow \vec{B}_A$ reaches peak value before $\vec{B}_M$

$\Rightarrow$ one of the rotating magnetic fields ($B_{M_{cw}}$ & $B_{M_{ccw}}$) becomes larger than the other.

⊛ إذاً من خلال الملف الاضافي عملنا على تقوية احدى المجالات (B_{cw}, B_{ccw}) وإضعاف
الآخر ، لذا بيكون Rotating mag field

$\Rightarrow$ The result is a rotating magnetic field $\Rightarrow$ there will be a relative speed between $\vec{B}_s$ and the rotor itself ~~was~~ where $\vec{B}_s = \vec{B}_A + \vec{B}_M$



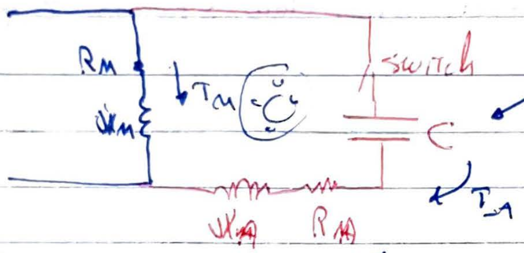
⊛ [To make higher starting torque you should make i_A more leads with i_m.

Note: its used in applications that do not require high starting Torque such as a fan and pump.

② The direction of rotation is reversed by switching the connection of either main windings or auxiliary windings

42 a (31)

② .1 Capacitor-start 1-Φ IM

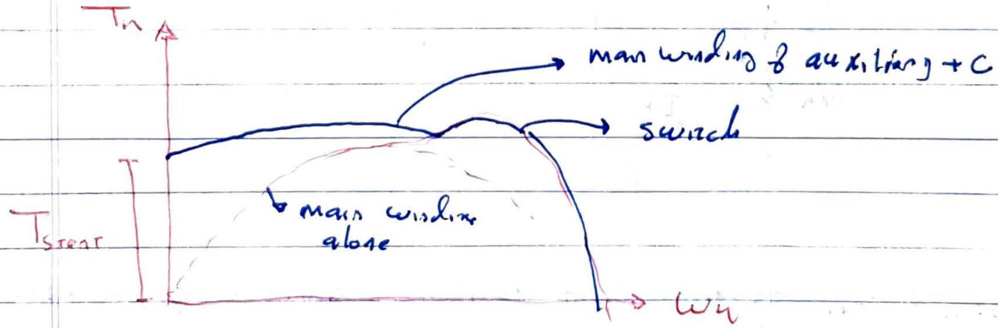


This make it more expensive than the split phase Technique

The capacitor is small size, is selected such that $\vec{I_A}$ leads I_M by 90° and the mmf_A equals the mmf_M At starting

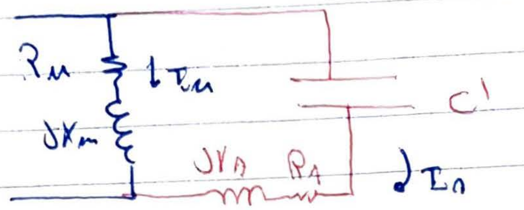
كل هذا الكلام عن البداية فقط.

=) This method gives higher starting torque than the starting Torque provide by the split-phase method



So $T_{start\,(2.1)} > T_{start\,(1)}$

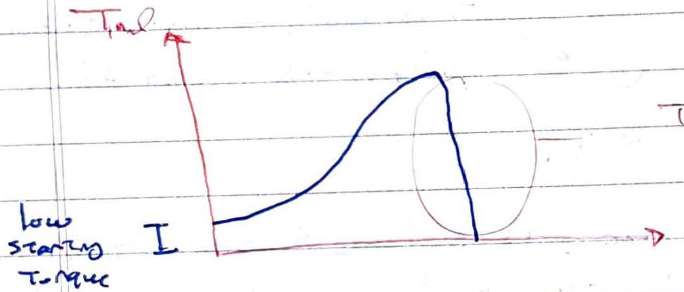
2.2) Capacitor Start & Run motor.



$C > C'$

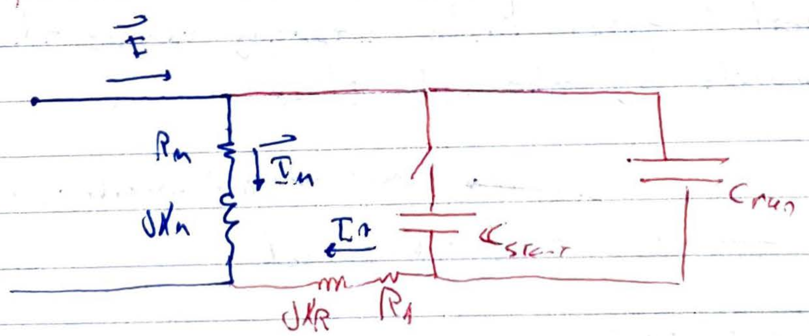
The capacitor C' of small size is selected such that $\vec{I_A}$ lead $\vec{I_M}$ by 90° & mmf at normal Load condition

⟹ This method improves the power factor & efficiency of the machine, However its gives low starting Torque.



This mean good power F & Yeff

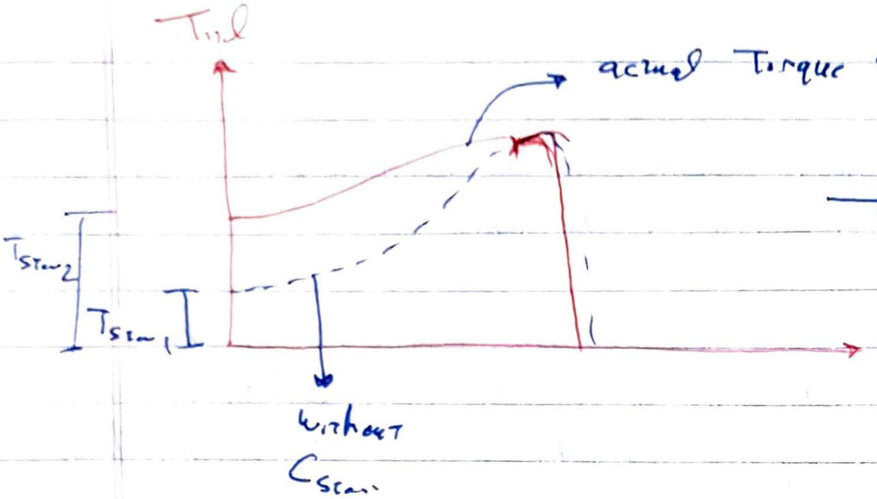
2.3) Capacitor Start & Capacitor run 1-Φ IM.



- C_{start} & C_{run} balances the auxiliary & main windings, at starting & increase the starting Torque.

- C_{run} balance the auxiliary & main winding at normal Load conditions to improve the motor PF & efficiency

Applications: compressor, Air conditioner



$T_{start2} > T_{start1}$

② speed control of 1-ϕ IM

" split-phase, capacitor type "

1) changing the number of poles, $n_s = \frac{120}{P} f_e$
2) changing the electric frequency, $n_s = \frac{120}{P} f_e$ → inverter / → cycloconverter
3) changing the Voltage applied to the main windings

(cheapest) 3.1) Inserting a resistor in series with the main winding.
3.2) AC Voltage regulator → TRIAC → its causes harmonic & Vibration
3.3) Auto-Transformer (expensive)

→ but increases the power losses

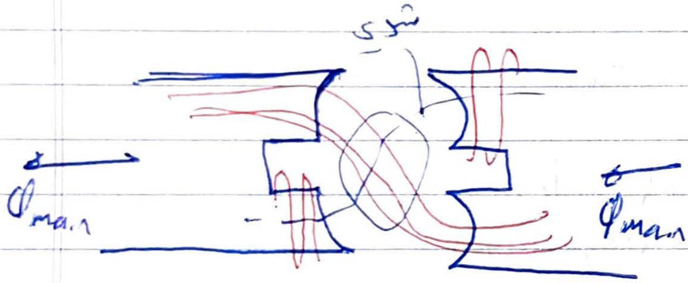
③ shaded pole - 1-ϕ IM

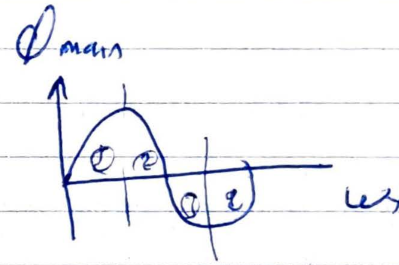
- Construction: its has a main (stator) winding with salient poles. one portion of each pole is surrounded by a short-circuit coil, called shading ring.

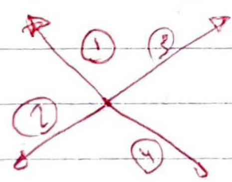
- operation

- when an Ac voltage is applied to the main windings it will induce an Ac flux in the core.

- The flux produces a voltage and a current in the shading coils. The current in the coil will induce a flux opposes the change in the original flux (lenz law)
- The result is slight imbalance between two opposite rotating flux ⇒ they will cause weak non-uniform rotating magnetic field.



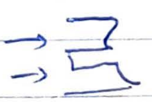




Rotating magnetic field

① يتم ربط الملف بـ Ac فولت

② 2poles كل واحد عليه

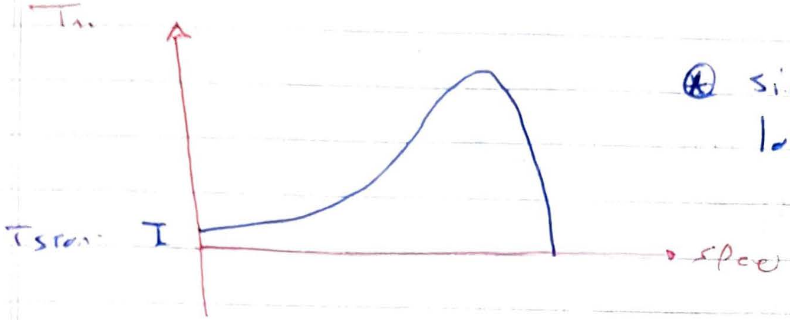


③ عند وضع مرور الوجه ينشأ flux Ac حسب Ac
عند امرار الملف ينشأ فولت, وحسب لينز تعاكس

④ عكس الدوران من عكس shading coil لـ الدوران من
shaded لـ unshaded

(Fan)

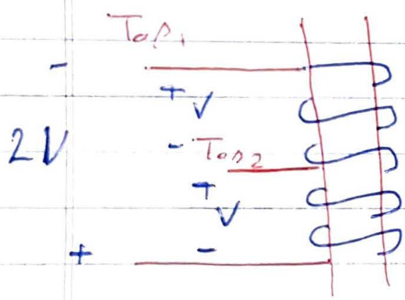
Torque speed curve



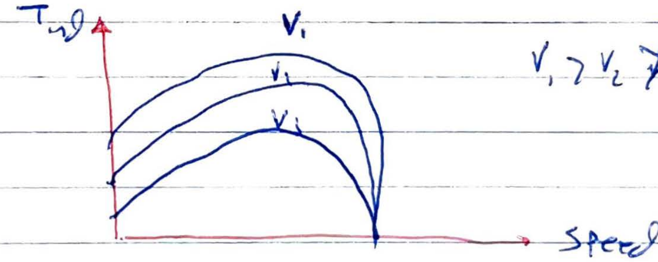
- simple, cheap but has low starting Torque & efficiency

Speed control for shaded pole Motors:

it's done by using the main winding as auto-Transformer

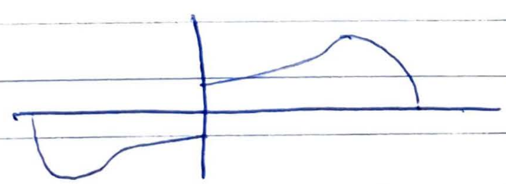


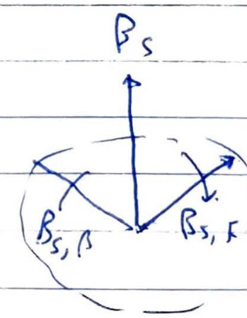
- when V is applied to Tap1 $\Rightarrow V_{motor} = V$
  when V is applied to Tap2 $\Rightarrow V_{motor} = 2V$

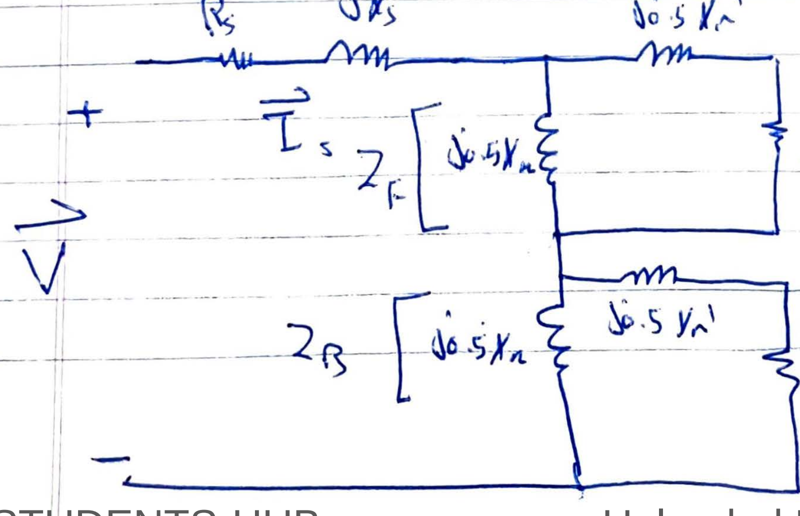


$V_1 > V_2 > V_3$

- equivalent circuit







$\frac{R_r'}{\alpha_F}(0.5) = \frac{0.5R_r'}{\alpha}$

$\frac{R_r'}{\alpha_B}(0.5) = \frac{0.5R_r'}{2-\alpha}$

حل مثال آخر الكتاب

$$\alpha_F = \frac{\omega_s - \omega_m}{\omega_s} = \alpha$$

$$\alpha_B = \frac{-\omega_s - \omega_m}{-\omega_s} = 2 - \alpha$$

$$T_{ind} = \frac{P_{AG}}{\omega_s} = \frac{P_{conv}}{\omega_m}$$

$$P_{AG} = P_{AG(F)} - P_{AG(B)}$$

$$P_{AG(F)} = I^2 (0.5)(R_F)$$

$$P_{AG(B)} = I^2 (0.5)(R_B)$$