ElCoM
ELECTRICAL COMPUTER MECHATRONICS

تقدم لجنة ElCoM الاكاديمية

تلخيص لمختبر:

مختبر الات وقيادة كهربائية

جزيل الشكر للطالبة:

سارة آبو سارة

Drive Lab Summary

Exp(1) Basic Measurements

theoretical part ⇒

- DMM "digital multimeter", to measure electrical quantities such as (V, I, R, P) and show these values digitally.
- Voltmeter, it has a large internal resistance which is considered as an open CCT during calculations, connecting in parallel with the electrical/electronic component(s).
- Ammeter, it has a small internal resistance acting as a short CCT during calcul connecting it in series with the electrical component.
- Wattmeter, electrodynamic device consists of :
  ① pair of fixed coil (current coil) which they connected in series with the CCT Load. and they're made up of few turns of a comparatively large conductance.
  ② movable coil (potential coil) which is connected across the line and consists of many turns of fine wires.

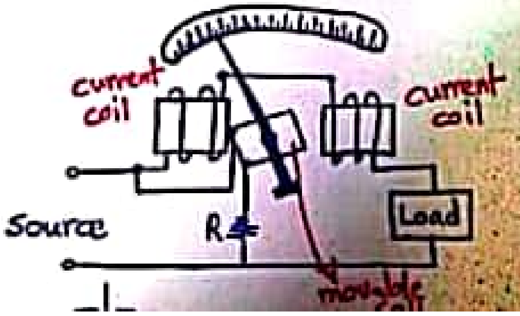
It's mounted on a shaft, carried in jeweled bearings, so that it may turn inside the stationary coils. It carries a needle which moves over a suitably marked scale, which holds to the zero position by spiral coil springs.

مبدأ العمل للـ wattmeter كيف بيشتغل؟!

When (Line current) flows through the current coil, a field is setup around the coil
وقوة المجال المغناطيسي الناتج تتناسب طردياً مع التيار المار
and in phase with it.

بالـ (potential coil) بيحتوي ع مقاومة عالية جداً متصلة بالـ movable coil للـ [meter] → (purely resistive), so the current in it in phase with line voltage.

ومن المجال المغناطيسي الناشئ والـ [movable coil] تنشأ ⇐ actuating force which proportional to the Instantaneous values of line current and voltage.



Three phase power system and PF :-

- 1ϕ generator ≡ an ac generator that's designed to develop a signal sinusoidal voltage for each rotation of the shaft (rotor).
- Polyphase generator ≡ develops more than one ac phase voltage per rotor rotation.

1ϕ → used in most small emergency generators (gasoline type)
2ϕ → used in servomechanisms
3ϕ → used by almost all commercial electric generators

مهم جداً

Why 3ϕ system is preferred over 1ϕ systems for power transmission ?!

① Thinner conductors can be used to transmit the same kVA at the same voltage because the current is divided among the 3 phases instead of between just one, and this reduces the copper required (25% less) so that reduces also construction and maintenance costs.

② The lighter lines are easier to install and the supporting structure can be less massive and farther apart.

③ Large motors are 3ϕ because they're self starting and don't require a special design or additional starting circuitry.

④ Easier motor wiring that doesn't require brushes, start capacitors, or any of the complexities of 1ϕ motors, and are easy to reverse as needed;

⑤ Constant power delivery, the 3ϕ each time a phase crosses zero there's still power being delivered, and this leads to 3ϕ motors in machinery running more smoothly.

- The frequency generated is determined by → shaft speed, → motor no. of poles

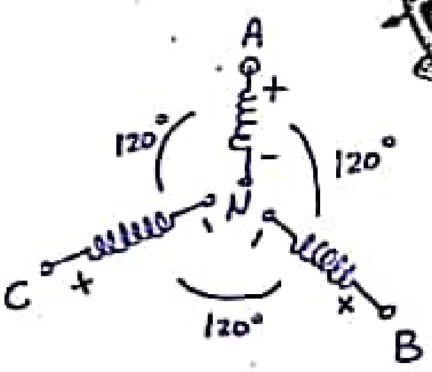
$F_{Jordan, Europe} = 50\ Hz$

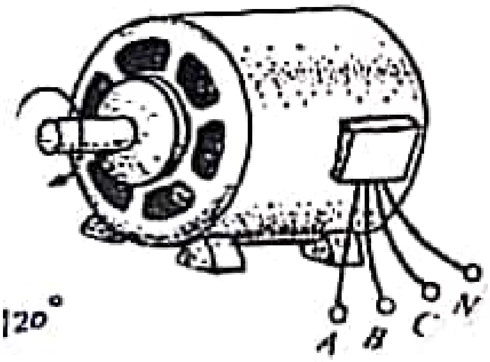
$F_{US} = 60\ Hz$

$F_{ships, aircraft} = 400\ Hz$

$$n_{[rpm]} = \frac{120 f}{P}$$

- 3ϕ generators →





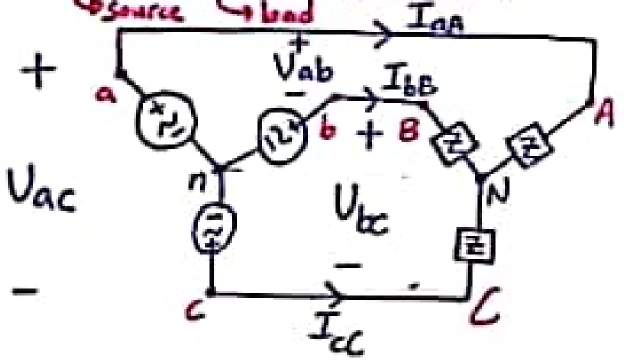
∴ $e_{AN} = E_{AN} \angle 0°$ ← phasor form

$e_{BN} = E_{BN} \angle -120°$

$e_{CN} = E_{CN} \angle -240°$

Combination of sources and loads :-

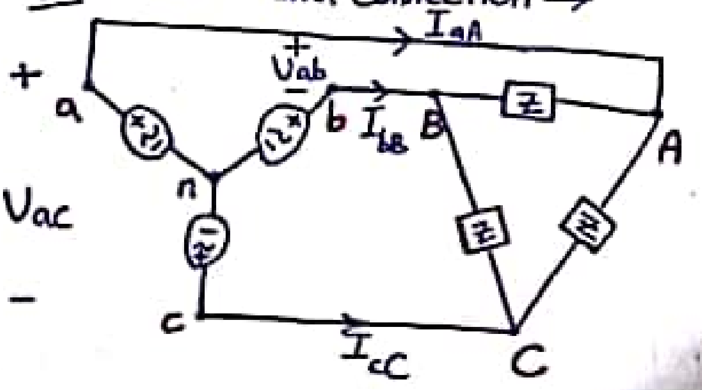
1] Star – Star Connection → (source → load)



$V_L = \sqrt{3} V_P$
$I_L = I_P$

, V_L lead V_P by 30°

2] Star – Delta Connection →



$V_L = V_P$
$I_L = \sqrt{3} I_P$

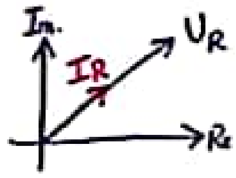
, I_P lead I_L by 30°

اللي منشغلها بالمختبر عادي لأنه السورس بكون مشبوك عالستار

- Loads → resistive / Capacitive / inductive, or combination of them –

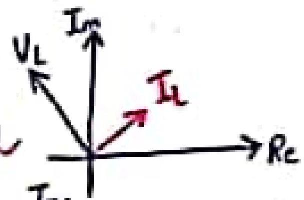
Resistive : I in phase with U

PF = 1



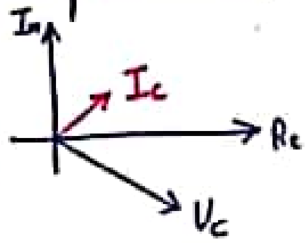
Inductive : I lagg U by 90°

PF = ∅ lagging



Capacitive : I lead U by 90°

PF = ∅ leading



- 3ϕ power calculations :-

AC power flow has three components →
- القدرة الفعالة Real power (active) [W] (P) consumed as heat losses
- القدرة غير الفعالة Reactive power (Q) [VAR] absorbed by inductive loads or generated by capacitive loads.
- القدرة الظاهرية Apparent power (S) [VA]

⇒ $\theta = \tan^{-1}\frac{Q}{P}$

$PF = \cos\theta$

⇒ The power supplied to or drawn by a 1ϕ is : $P_\phi = V_\phi I_\phi \cos\theta$

$$P_{tot} = 3U_\phi I_\phi \cos\theta = \sqrt{3}\, U_L I_L \cos\theta$$ → by 3ϕ

- Voltage Regulation → فرق الجهد بين الفولتية الطالعة من السورس لما يكون بدون لود عن لما أحط لود بسبب وجود ($R_{internal}$) بتعمل (U_{drop}) ..

the percentage of voltage difference between no load & full load voltages of a source with respect to its full voltage load.

$$\%UR = \frac{V_{2\,(no\,load)} - V_{2\,(with\,load)}}{V_{2\,(with\,load)}} \times 100$$

أفضل شي انه يكون (0V) تقريبا

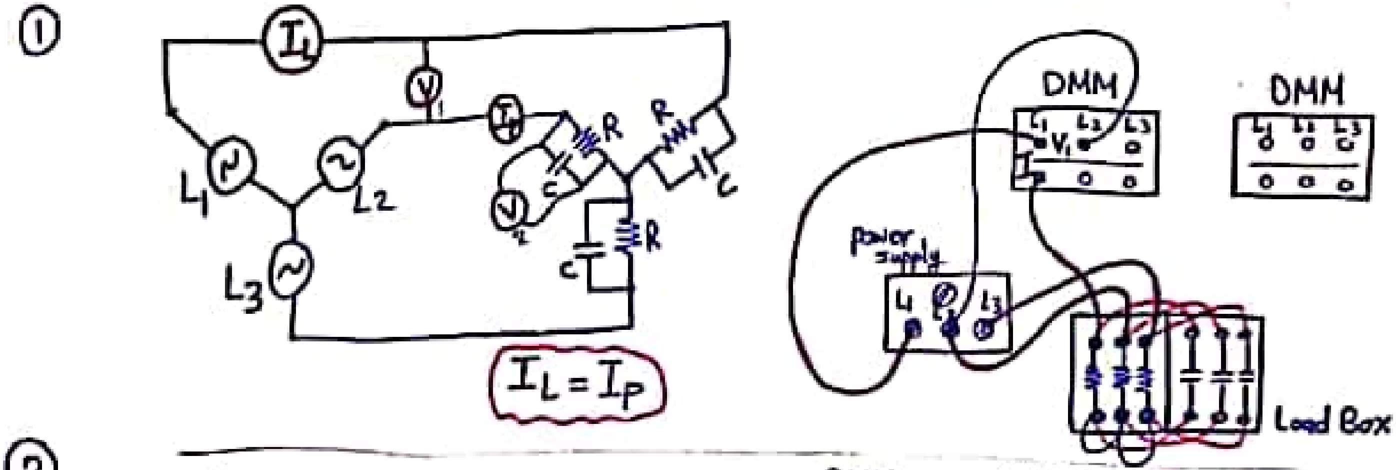
- it can be measured by →
  - fixing the load, changing (V_{source}) using autotransformer ويتغير عندها الفولتية في حالة الـ (no load)
  - fixing the supply voltage نحط كل اللود ونختبر عليه ونقيس الجهد عند الـ (full load)

practical part ⇒

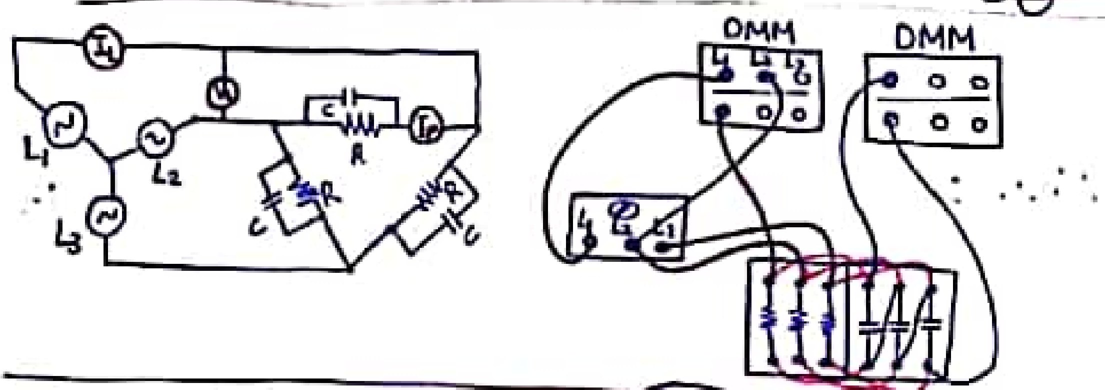
بوصّل الأميترات أول شي دايمًا
بعدين الفولتميتر

Connect the circuits shown below :

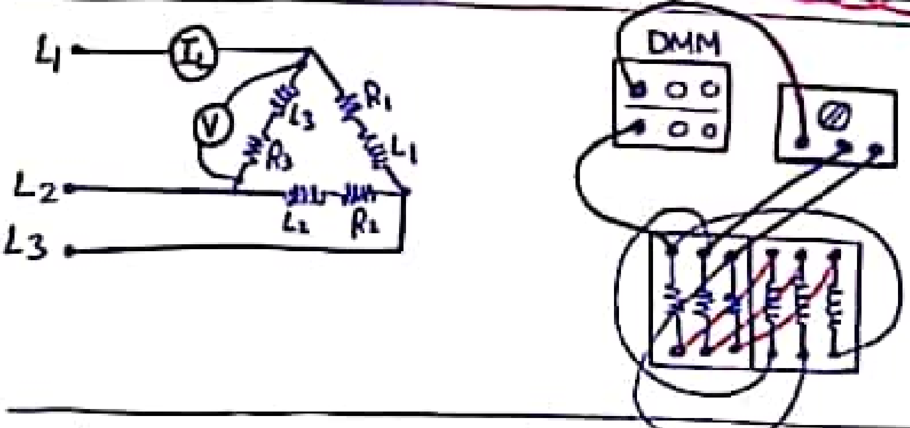
①



②



③



Quiz (1)

Q1) Based on the table, answer the following :

$V_L = 219.2V$	$I_L = 3.01A$	
$V_P = 218.2V$	$I_P = 2.3A$	$P_P = 121.4\ W$

من الجدول منستنتج انه التشبيكة على ال delta

1. What's the total real power?

$P_{tot} = 3 * P_P = 3(121.4) = 364.2\ W$

2. If the load connected in star instead of delta, what's the value of total real power will be? 364.2 W (بتضل زي ما هي)

3. If the U_L without load equal 220V, find the voltage regulation?

$UR(\%) = \frac{220 - 219.2}{219.2} * 100 = 0.36\%$

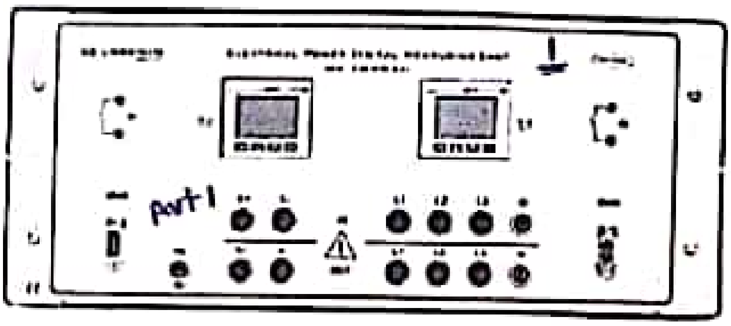
Q3) جابولنا صور للـ (units) وطلبوا منا ...

a. What's the purpose of unit (1)?

→ (DMM) to measure electrical quantities such as U, I, P, PF, ...

b. Can I use unit 2, part 1 to measure the phase voltage. Explain?

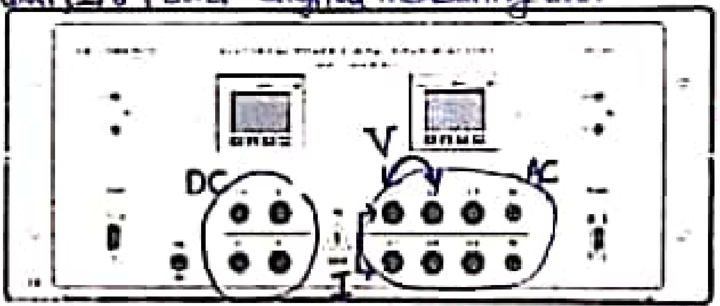
→ No, because it's for dc voltage measurement so it'll give us a zero reading in the AC measurement.



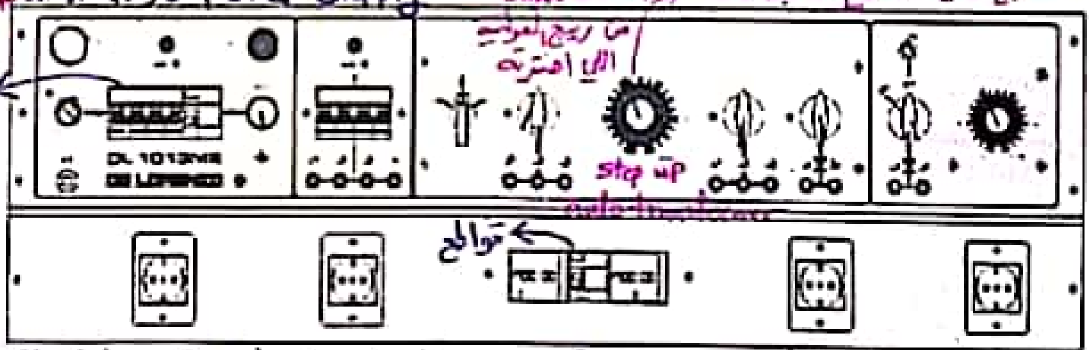
Notes :-

Apparatus:

unit (1): Power digital measuring unit



unit (2): Power supply



unit (3): Resistor, Inductor, capacitor boxes / Loads

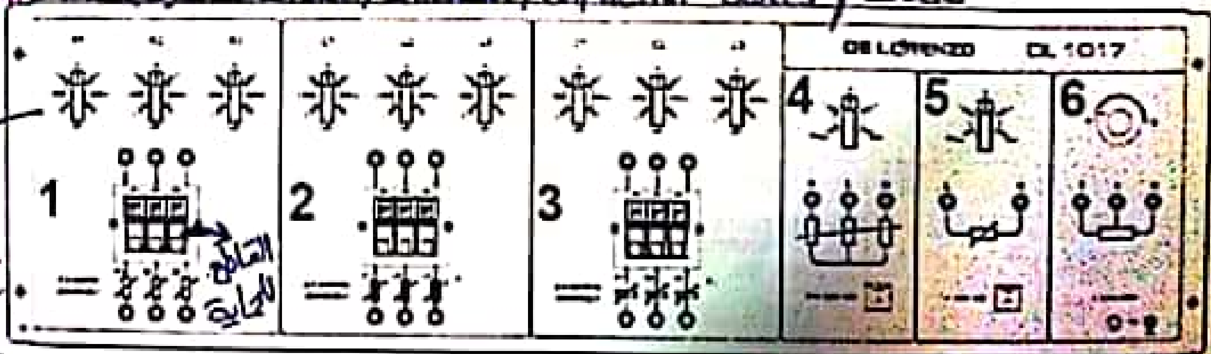


Figure 1.1: System Apparatus

Exp (2) Transformers

- It's an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction, that produces an electromotive force within a conductor, which is exposed to time varying magnetic fields.

يستخدمه للزيادة أو للتقليل من ال (alternating voltages) in electric power application

- Varying current in the transformer's primary winding creates a varying magnetic flux in the transformer core, and a varying field on the transformer's secondary winding which induces a varying emf due to electromagnetic induction.

Transformer's Core and shell forms →

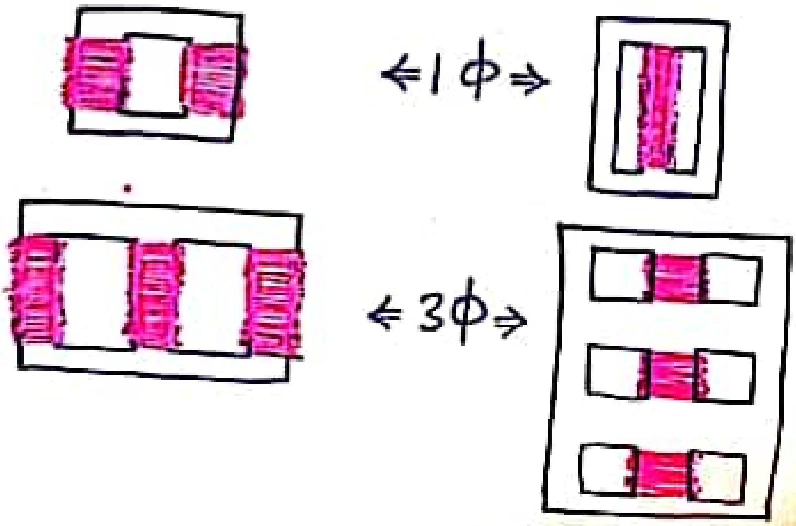
Closed core transformers are constructed in :

① Core form ↲ windings surround the core

- more economical for high voltage power transformer applications at the lower end of their voltage and power rating ranges (⩽ 230 kV or 75 MVA)

② Shell form ↲ windings surrounded by the core

- more prudent for transformer distribution applications due to the relative ease in stacking the core around winding coils.
- They're characterized as having better kVA to weight ratio, better short CCT strength characteristics and higher immunity to transit damage.



Transformer Tests →

An important point is to define the transformer's low voltage side and high voltage side.

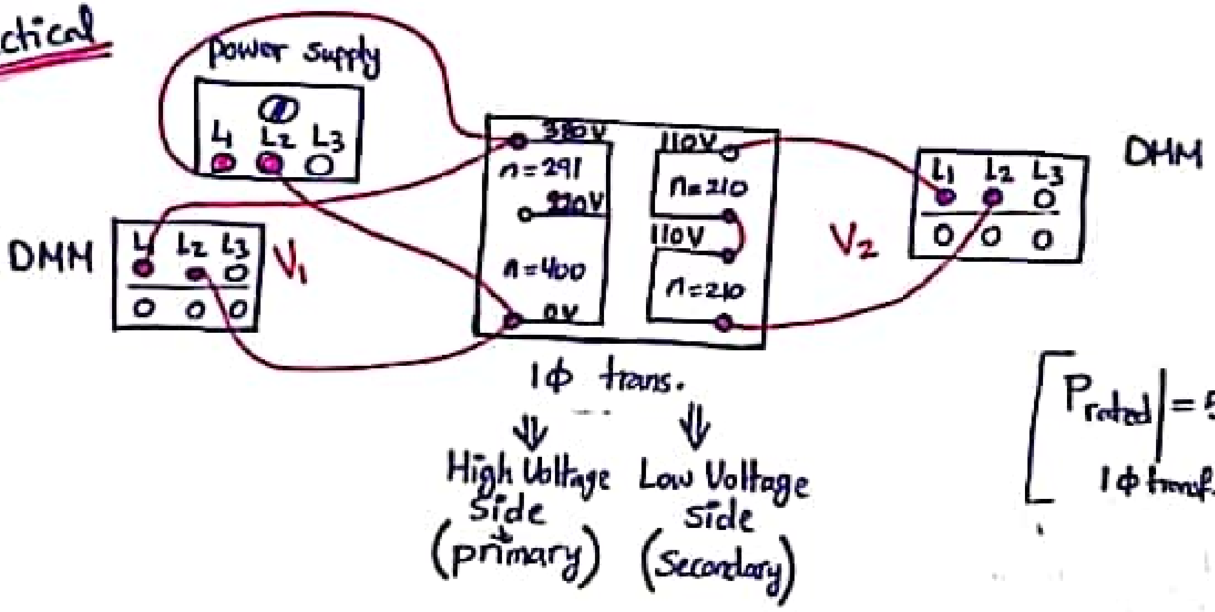
1) Turns ratio test : (at no load)

بتطبيق فولتية معينة على الـ (primary) ونقيس بالفولتميتر الفولتية الخارجة من الـ (secondary)

$$a = \frac{V_P}{V_S} = \frac{I_S}{I_P}$$

↳ for ideal transformers "no losses"

practical



[P_{rated} = 500 W
1φ transf.]

* ويمكن أضيف لود (load) مع ملفات الـ (secondary) وأحسب (V_2) بوجودها ويطلع الـ VR

Notes :

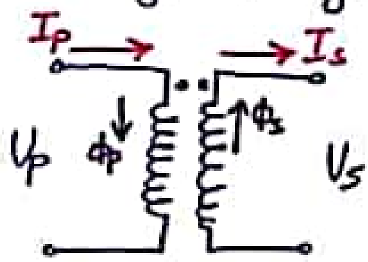
- بالـ (1φ transf.) ⇐ PE الموجود فيه منستخدمه لتفريغ الشحنات والكهرباء الساكنة من على جسم المحوّل على اعتبار انه منشغله بشكل سريع ولفترات طويلة ..
ليس ما منستخدمه بالـlab لأنه ما منشتغل على المحول بالكمية الكبيرة اللي غالبا نحتاجه

- إما بنقيس (V_{S1}) and/or (V_{S2}) ، (V_{P1}) or (V_{P2}).

2.] Windings polarity test (Dot Convention):

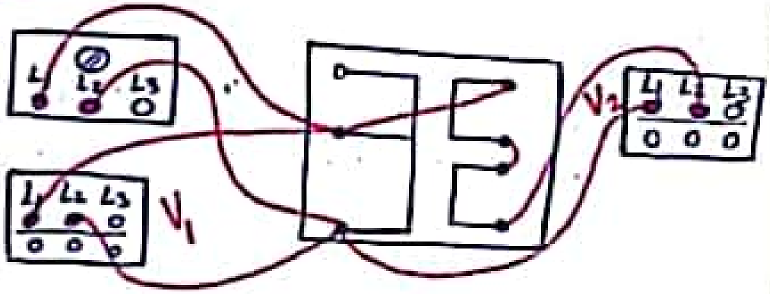
- Voltage polarities are the same with respect to the dots on each side of the core.
- If the current flows to the dotted end of the primary, the I_s will flow out of the dotted end of the secondary winding.

because when I_p induce Φ_p in a certain direction, the secondary coil will induce Φ_s that will oppose the Φ_p in direction.



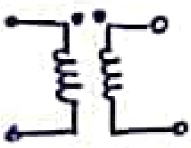
(مهم جداً) [Importance of polarity test] → to know the relative polarities at any instant of the primary and the secondary terminals for making the correct connections if the transformers are to be connected in parallel or they're used in a 3ϕ circuit.

practical



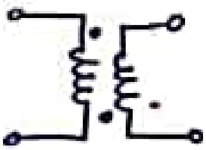
بطبق فولتية على ال primary (V_1)
ونعمل شورت بسلك بين واحد من أطراف ال primary مع واحد من أطراف ال secondary
ونقيس الفولتية اللي بتطلع من ال unshorted terminals (V_2)

* if $v_1 > v_2$, subtractive



→ the transformer voltage are in phase

if $v_1 < v_2$, additive



→ the transformer voltages are out of phase

3] Load Test :

بيكون الـ primary مشبوك مع الـ(Supply voltage)
واللود بيكون مشبوك على الـ secondary
وبقيس الفولتية الخاملة وبقارنها بدون اللود لأحسب (UR)

- The with-load (η_{actual}) → $\eta_{actual}(\%) = \frac{P_{out}}{P_{in}} * 100$ ، $P_{out} = I_2 V_2$ (for a purely resistive load)

(η_{max}) occurs when $[P_{cu} = P_{iron}]$

$P_{in} = P_{out} + P_{cu} + P_{iron}$

- Because a real transformer has series impedence within it, the output voltage from it varies with load even of the input voltage remains constant.

$$UR(\%) = \frac{U_2(\text{no load}) - U_2(\text{with load})}{U_2(\text{with load})} * 100$$

U_2(with load) → secondary voltage

→ مستناها عليًا تثبيت الجهد وعدم تأثره باللود مع بقاء (Rprotec) ثابتة

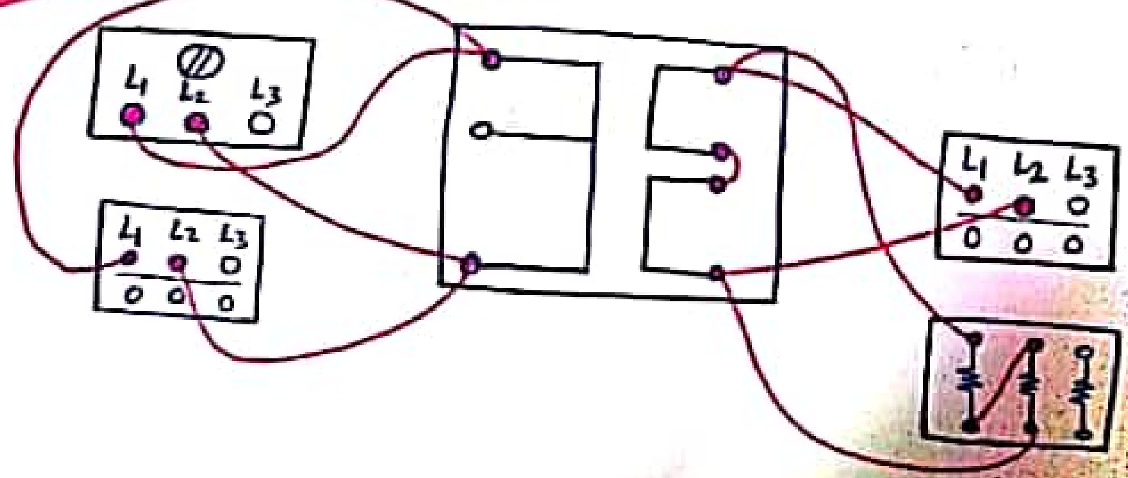
مهم جدًا
- To protect the transformer, ($R_{protec.}$) added in series with the (load) with a min. value → to prevent ($I_{secondary}$) to exceed its rated value.

$$I_{rated} = \frac{P_{rated}}{V_{rated}} = \frac{500\,W}{(320) \text{ or } (220)} \,[A]$$

$$R_{min} = \frac{V_{rated}}{I_{rated}} \,[\Omega]$$

حسب شو الفولتية اللي أعطيتها الـ primary

practical



4) Three phase connection :
(Star/Delta)

- **Star Connection →**

advantages

a. allows the 4 wire distribution
b. allows the phases to be insulated for a voltage 1.73 times less than the line voltage
c. star centre can be connected to earth and this stabilizes the voltage value.

مهم جداً

disadvantages

a. when used on the primary, it doesn't allow the free flowing of the 3rd harmonic
b. this rise to deformation of the flux waves and the phase voltages

- **Delta Connection →**

advantages

مهم جداً

a. when used on the primary, it imposes the values of the phase voltage under any load condition, therefore ensuring the voltage symmetry
b. allows the free flowing of the 3rd harmonic .
c. doesn't introduce any deformation of the fluxes and the voltages.

d. when used on the secondary, it dampens 3rd harmonic of the fluxes leaving the induced currents free to flow
e. it allows the reduction of the winding sections, which are sized for a current 1.73 times smaller .

disadvantages

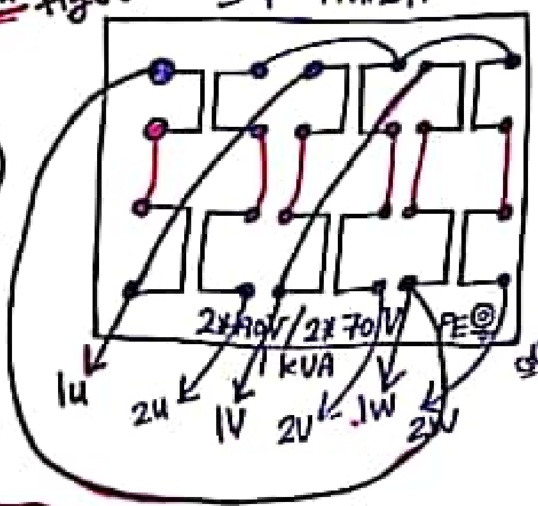
a. it doesn't allow 4 wire distribution (in the output side)
b. it doesn't allow the earth connection
c. so, in case of the earth fault, could be even stressed by the whole line voltage

مهم جداً * the most suitable connections are → primary (delta)
Secondary (star)

في حالة كنا جاية لخط النتر
أو الخط الأرضي
ما عدا ذلك بنعكسها عادي

practical Fig(1) 3 ϕ transf.

أمين توصيله



$V_P = 190$ V

$V_S = 70$ V

Series delta/Series star

(delta → primary, star → secondary)

Rated line voltage →

- $V_{HV} = 2 * 190$ V $= 380$ V (delta : $V_L = V_P$)

لأن مستخدم الملفات اللي فوق واللي تحت

- $V_{LV} = \sqrt{3} * 2 * 70 = 245.5$ V (Star: $V_L = \sqrt{3} V_P$)

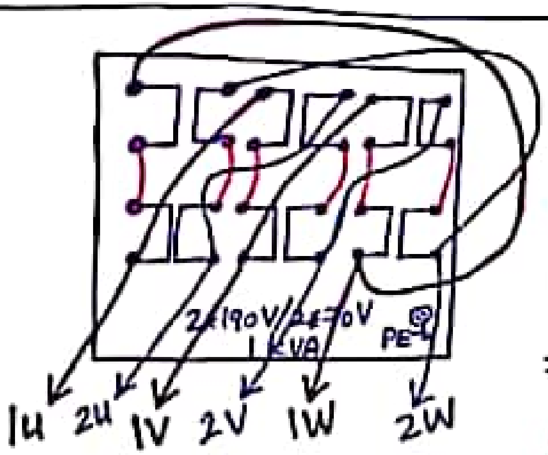
Rated line current →

- $I_{HV} = \sqrt{3} * \frac{1000 \text{ VA}}{3*(2*190)} = 1.52$ A (delta: $I_L = \sqrt{3} I_P$)

لأن مستخدم ال ٣ ملفات كل الملفات

- $I_{LV} = \frac{1000 \text{ VA}}{3*(2*70)} = 2.38$ A (Star: $I_L = I_P$)

Fig(2)



Series delta/Series delta

Rated line voltage →

- $V_{HV} = 2*190$ V $= 380$ V
- $V_{LV} = 2*70$ V $= 140$ V

Rated line current →

- $I_{HV} = \sqrt{3} * \frac{1000 \text{ VA}}{3*(2*190)} = 1.52$ A
- $I_{LV} = \sqrt{3} * \frac{1000 \text{ VA}}{3*(2*70)} = 4.12$ A

Discussion & Analysis Questions

Q1) Does the transformer voltage ratio stay the same when a load is applied? Why?

→ No, due to the drop voltage occurs on the internal impedences of the primary & secondary that increases due to loading current (I^2R) so V_2 drops at the same V_1

Q2) Why does the wattmeter in the noload test read the iron core losses only?

→ because the voltage in it's approximate the rated. So, the iron losses that depends on the voltage across the windings, is considerable.

$P_{iron} = I^2R$

Exp(3) Shunt DC Motors

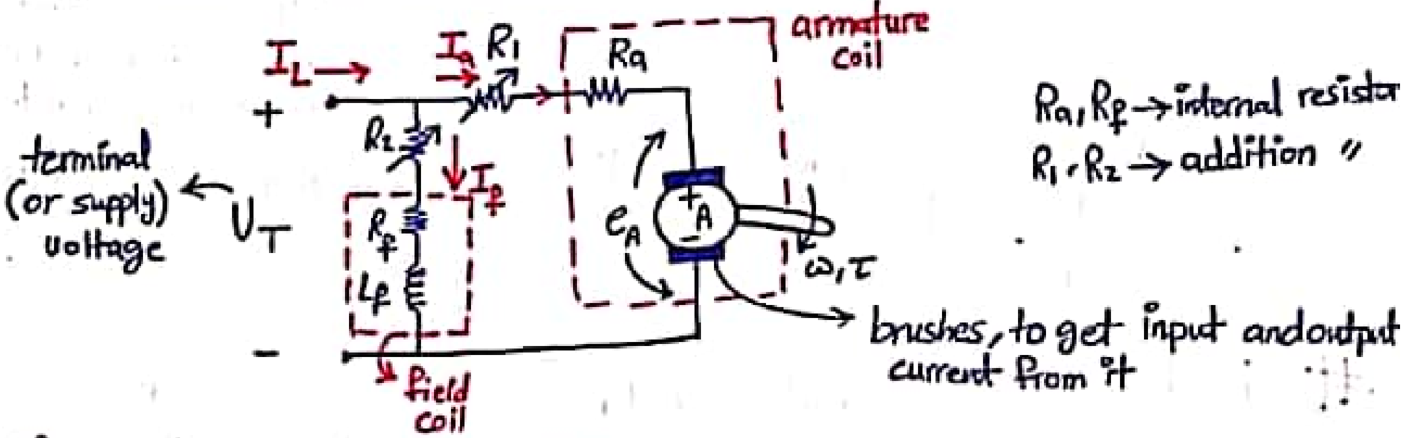
theoritical Part ⇒

بيشبه لحد كبير الـ [Separately Excited DC Motor] لكن الفرق هو:

- SEDM → has its field CCT connected to an indep. Voltage supply
- SDM → has its field CCT connected across the armature motor terminals.

• وعلى فرض انه الـ supply voltage ثابت فإن مبدأ عمل كلا منهما هيكون نفس الشيء.

Equivalent Circuit of a shunt DC Motor →



if $[R_1 = R_2 = \emptyset]$ → $V_T = e_a + I_a R_a$, where $\left[\begin{array}{l}\tau = k\phi I_a \\ e_a = k\phi\omega \\ I_L = I_a + I_f\end{array}\right.$

$= k\phi\omega + \frac{\tau}{k\phi} R_a$

$$\boxed{\omega = \frac{V_T}{k\phi} - \frac{R_a}{(k\phi)^2}\tau}$$ → (τ-ω) relation (مهم)

* How does a shunt dc motor respond to a load ?

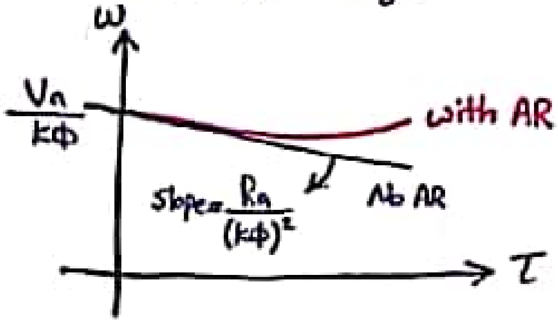
increasing the load that's connected to the motor shaft, will cause increasing in the (τ_{load}) exceed the (τ_{ind}) in the machine, so the motor starts to slow down.

ولما سرعة الموتور بتبلش تقل ← the internal generated voltage ($E_A\downarrow$)

$[\downarrow E_A = k\phi\omega\downarrow]$ so the ($I_a\uparrow$) $\left[I_a\uparrow = \frac{V_T - E_A\downarrow}{R_a}\right]$ and then ($\tau_{ind}\uparrow$) $[\uparrow\tau_{ind} = k\phi I_a\uparrow]$

until it equals to the τ_{load} at a lower mechanical speed of rotation.

← من خلال علاقة (τ-ω) السابقة ، حتى تتغير سرعة الموتور بشكل خطي مع التورك
لازم تكون كل المتغيرات الأخرى في العلاقة تمثلها ثابتة (R_a, Φ, V_t) → as load changes



(τ-ω) characteristics curve

- Linear relation with a negative slope
- [Armature Reaction] مشكلة بتأثر بشكل المنحنى نتيجة ←

as the load increases, the flux weakening effect occur and that causes the speed to increase over the speed at no AR at any given load.

حل هاي المشكلة ← by having a compensating winding in the motor that makes the Φ remains constant.

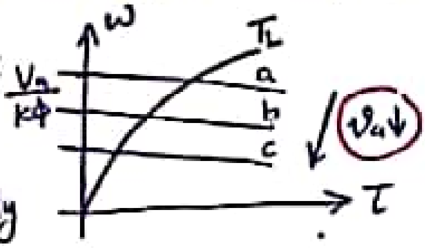
فنقدر نثبت السرعة على أي قيمة من اللود طالما بعرف مقدار (I_a)

Speed Control of a shunt DC motor → للتحكم في سرعة موتور الشنت (٣ طرق)

1] Armature Voltage :

للسرعات الأقل من (ω_{base})

requires variable DC supply

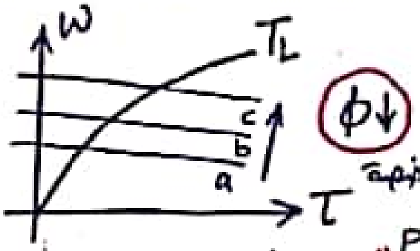


← مع نقصان $V_a \downarrow$
بتقل الـ $\omega \downarrow$
بتقل الـ $\tau \downarrow$

advantages → doesn't change speed regulation
→ speed is controlled from [0 - ω_{base}]

disadvantages → cost is higher because of using power electronic controllers

2] Field flux :



غير مُجدية لـ PMDC (permanent magnet DC motor)

السرعات الأعلى من (ω_{base})

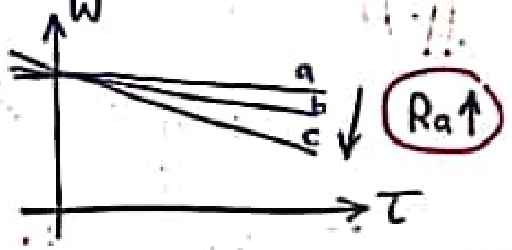
by changing R_f

← مع نقصان $\Phi \downarrow$
بتزيد $\omega \uparrow$
بتزيد $\tau \uparrow$

advantages → speed control above base
→ the cost of rheostat is small because it has small value.

disadvantages → speed regulation is poor
→ At high speeds flux is small thus causes the speed to become unstabl

3] Armature Resistance (R_a):



مو مشهورة كتير هاي الطريقة
because it reduces the motor efficiency due to the losses

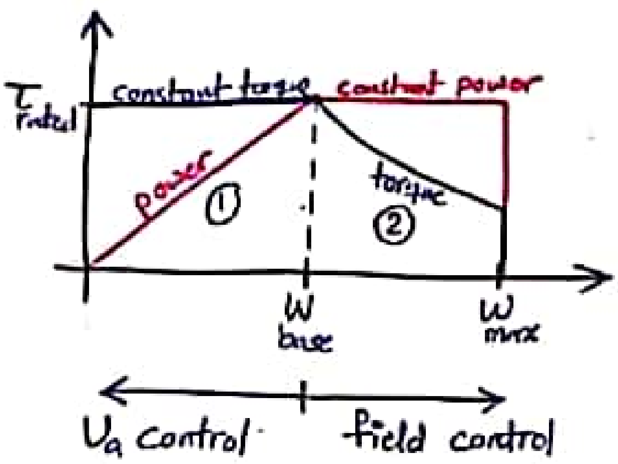
← بزيادة ↑R_a
بيزيد ↑slope
بـ ↓ω

advantages →
- starting and speed control combined in one rheostat
- the speed range begins at zero speed
- cost is less for the same speed range than other methods
- Simple method

disadvantages →
- Introduce losses in rheostat thus low η
- Speed regulation is poor

Motor Characteristics →

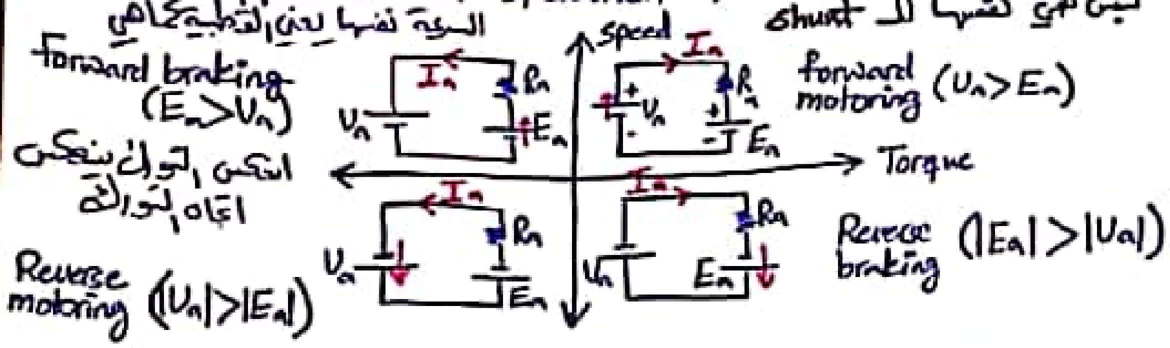
أي قيمة للتورك بتكون أعلى من ال (rated) will cause the shaft to stop "get locked"



$\omega_{max} = 30\% \ \omega_{rated}$

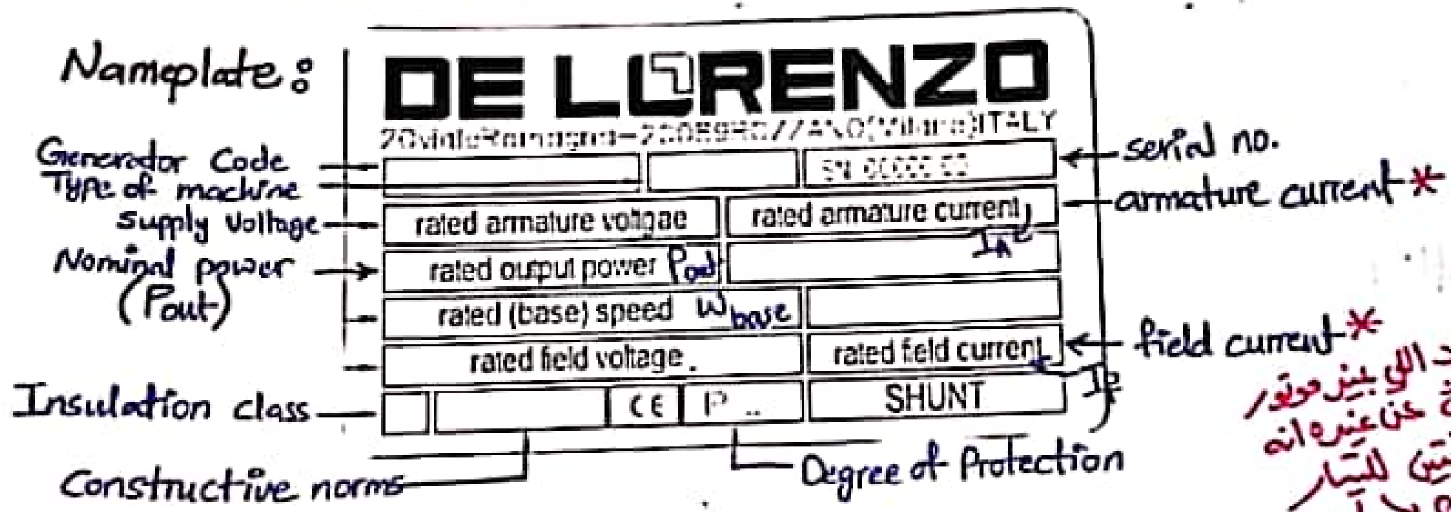
- In region (1): بيكون اللود ثابت ، لما بطبق V_t وبيصير عندي (T_{rated}) that can be applied to the shaft that can run at speeds up to the ω_{base}
- In region (2): مع زيادة السرعة لازم يقابلها نقصان على اللود المُركب مع الـ (shaft) لأنه اذا زاد اللود مع السرعة رح يزداد التورك وبالتالي رح يزيد سحب التيار اللي رح ينتج عن زيادة بالفولتية المطبقة ولكنها بالأساس شغالة V_t فقط ع ال rated value إلها فقط.

Modes of Operation → SEDM للـ
لبين هي نفسها للـ shunt



Practical part ⇒

Nameplate:



وهاد اللي بميز موتور الشنت عن غيره انه ما بحتاج للتيار f ← a

$I_a > I_f$

* القيم على الـ (name plate) عبارة عن قيم تشغيلية لكن الـ [max values] بتكون أكبر منها بـ 30%

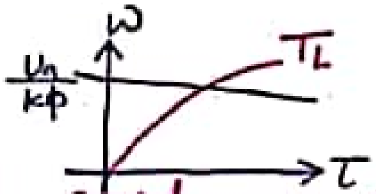
$$P_{in} = V_T (I_a + I_f)$$

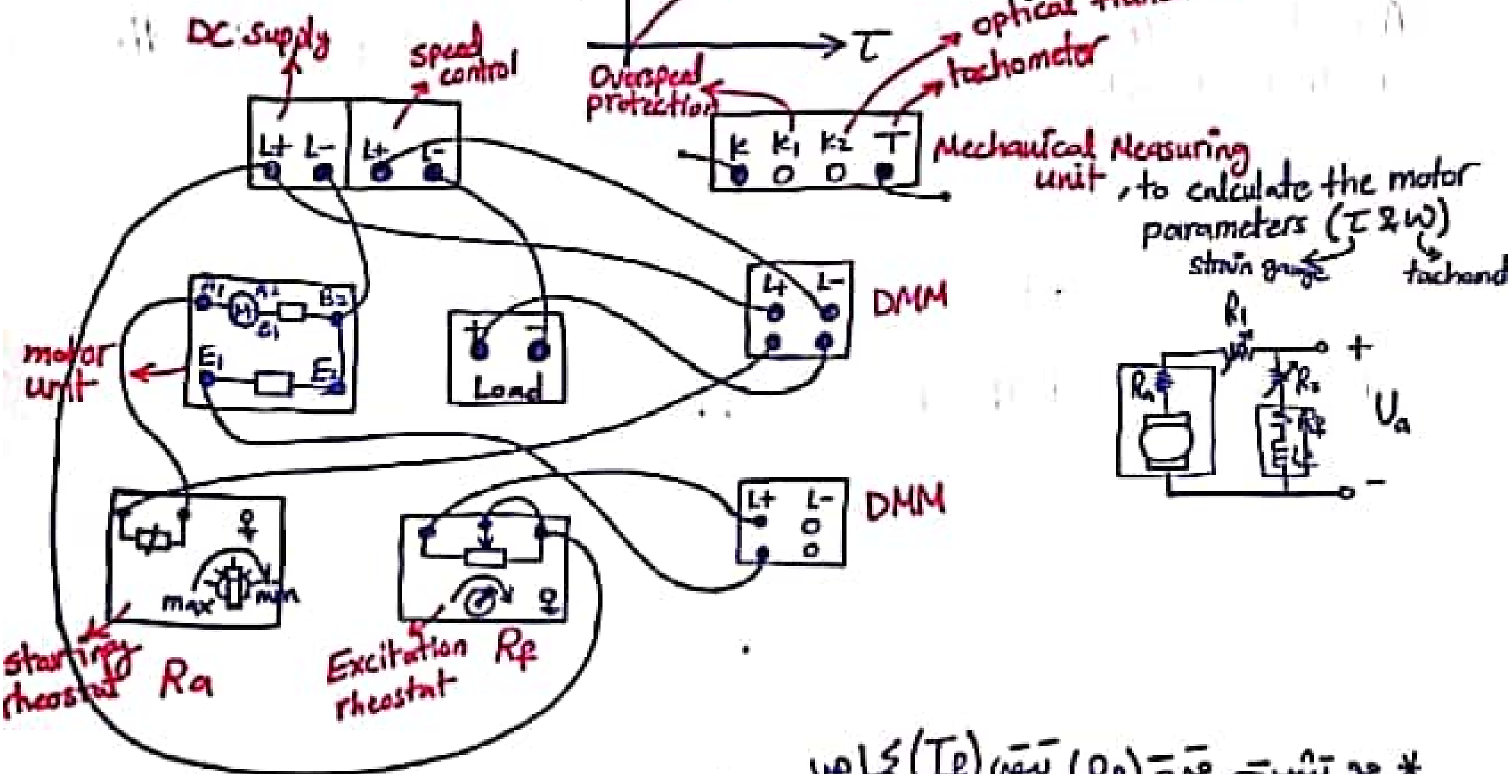
$$P_{out} = \frac{2\pi n \tau}{60}$$

$$\tau_{rated} = \frac{P_{rated\,(out)}}{\omega_{rated\,(base)}}$$

• In this Lab, we'll be looking at the properties of the shunt by increasing the load using an electromagnetic brake (load) to achieve pre-specified currents.

① ($\tau - \omega$) Curve →





* Starting Rheostat (Ra) :

used for starting & speed control.

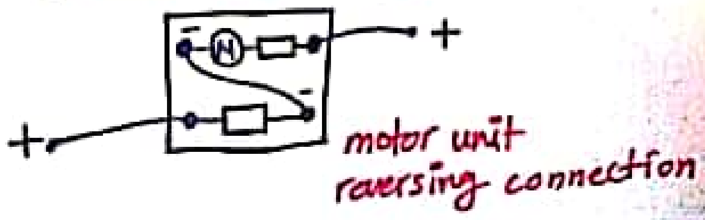
* مع تثبيت قيمة (Rf) تبقى (If) كما هي
بزيادة اللود تقل السرعة، فتقل ↓Ea
يزداد ↑Ia والتورك ↑τ

② Altering (Rf) → بزيادة Rf↑ تزداد (↑ω) مما

③ Altering (Va) → بزيادة Va↑ تزداد (↑ω)

④ Reversal of shunt direction → بعكس قطبية الـ (armature) أو الـ (field)

عكس قطبية الـ (armature) هو



Quiz Questions

- I can increase the flux of a shunt DC motor by dec. the field resistance.
- Main difference between speed control by voltage and field flux control in dc motors is the voltage to control speeds below the base & field flux for above the bas
- According to the terminal characteristics of the shunt DC motor, the method of control in the following fig. is U_T

- Increasing U_T of the shunt will not change the load torque.

CamScanner الممسوحة ضوئيا بـ

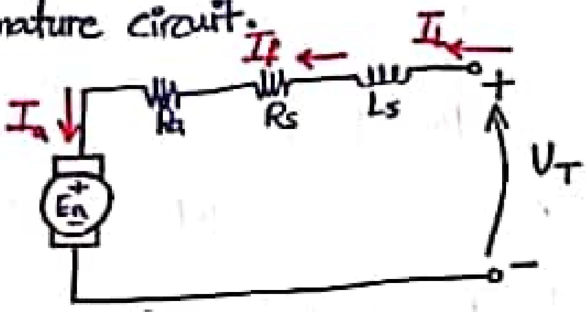
Exp (4) Series DC Motor

theoretical part ⇒

- It's a motor whose field windings consists of a relatively few turns connected in series with the armature circuit.

$I_A = I_f = I_L$

$V_T = E_a + I_a(R_a + R_s)$



- The basic behaviour of a series DC motor, due to the fact that $\phi \propto I_a$, at least until saturation is reached.

$$\phi = cI_a$$

⇐ مع زيادة اللود بيزداد ϕ فبتقل السرعة

$$\tau_{ind} = k\phi I_a = kcI_a^2$$

$$\tau_{ind} = kI_a^2$$

وهاد اللي بميز موتور ال series عن ال shunt انو بيعطي τ_{ind} عالي لهيك بيتم استخدام الموتور في

- starter motor in cars
- elevator motors
- tractor motors in locomotives

The terminal characteristics of a series dc motor:

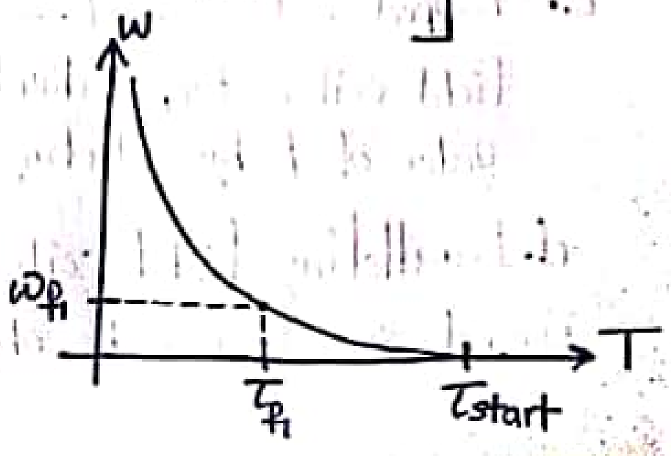
$$V_T = E_a + I_a(R_a + R_s)$$

$$I_a = \sqrt{\frac{\tau_{ind}}{kc}}$$

$$E_a = k\phi\omega$$

$$\Rightarrow \left[V_T = k\phi\omega + \sqrt{\frac{\tau_{ind}}{kc}}(R_a + R_s)\right]$$

$$\omega = \frac{V_T}{kc\sqrt{\tau_{ind}}} - \frac{R_a + R_s}{kc}$$



Series DC Motor

Disadvantage → When the motor torque goes to ∅, the speed will goes to ∞. In practice, due to the mechanical, stray and core losses the torque can never be zero.

If no other load connected to the motor, it can turn the motor fast enough to damage Itself.

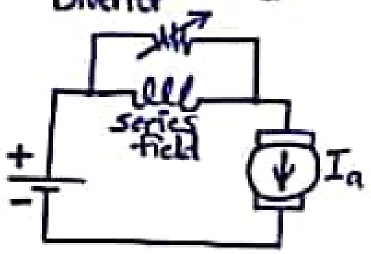
يعني أبدًا ما بصير أعمله unloaded على الموتور وهو شغال

Speed Control of series DC motor

1] Flux Control :

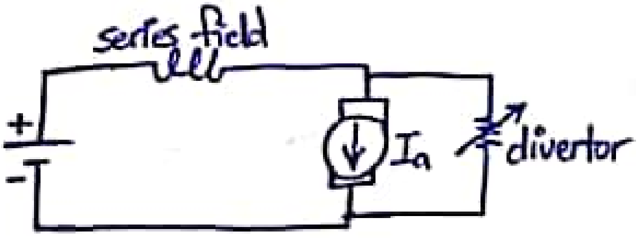
a. Field diverter → بإضافة مقاومة (R_{dN}) على التوازي مع (R_F) بتعمل على تقليل التيار (I_a) وبالتالي بتقل ϕ فبتزيد السرعة.

لكن مع استمرار الزيادة على قيمة (R_{div}) فتصير السرعة تساوي لقيمتها السابقة.



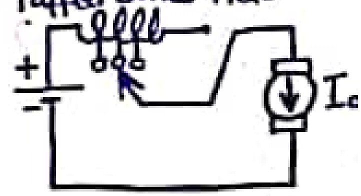
b. Armature divertor → For a given constant load (torque)

التيار (I_a) بيقل
(ϕ) بيزداد
فبتقل (السرعة)



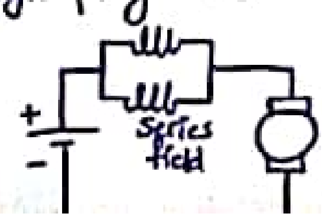
c. Tapped field control →

Field coil is tapped dividing no. of turns. Thus, we can select different value of ϕ by selecting different no. of turns.



d. Paralleling field coils →

Several speeds can be obtained by regrouping coils.



2] Variable Resistance In Series with Armature →

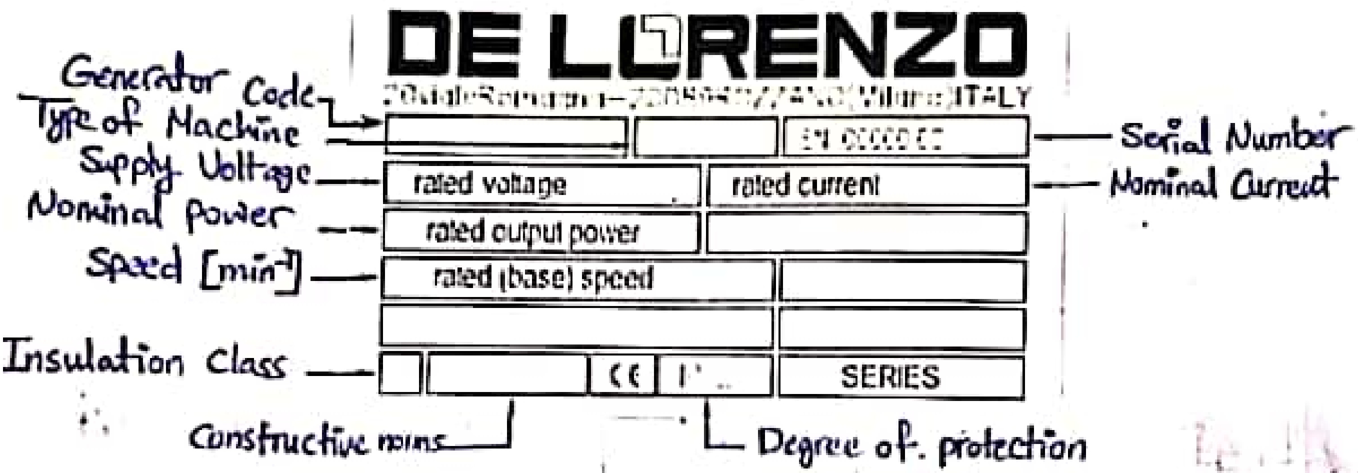
بإضافة مقاومة على التوالي مع R_a تقل (V_a) وتقل السرعة معه

3] Varying (V_a) →

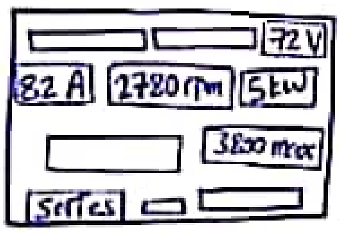
اذا تقل ال armature voltage تقل السرعة والعكس، $V_a \propto \omega$

- **Differences between shunt and series motors →**
  1. Series should be loaded all the time
  2. Torque in the series much higher than the T_{ind} in the shunt
  3. Cross sectional area of series > cross sectional area of a shunt
  4. Series no. of turns < shunt no. of turns

Series dc motor nameplate :-



Q mid



① Find T_{rated}?

$$T_{rated} = \frac{P_{rated}}{\omega_{rated}} = \frac{5\,kW}{\frac{2\pi}{60}(2780)} = 17.17$$

② Find $(k\phi)$ at the T_{rated}?

$$T_{rated} = (k\phi) I_a$$

$$17.17 = (k\phi)\,82$$

$$k\phi = 0.209$$

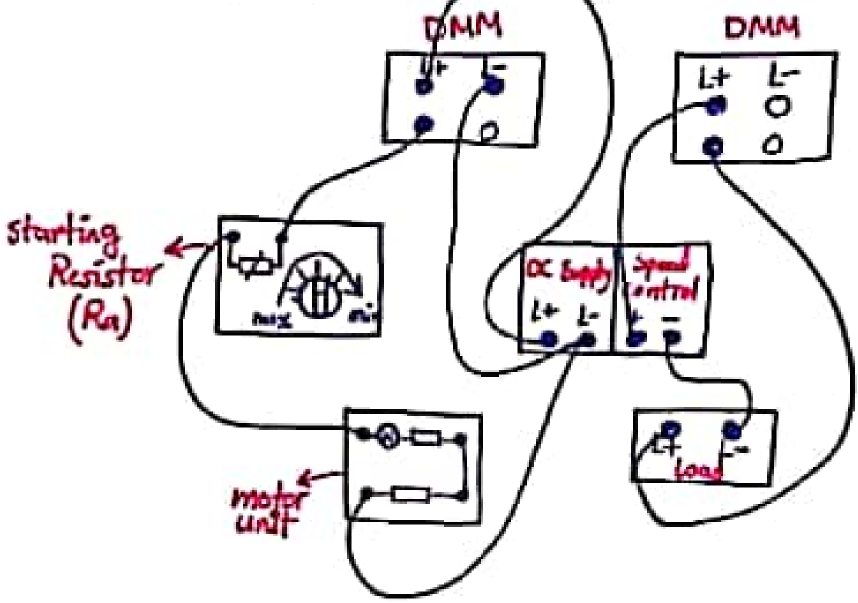
③ Find R_{total} assume no losses (mechanical)?

④ Find E_a assume no mechanical losses?

دائماً منشغل اللود أول شي عشان عند ال starting
بعدين لود ما بصير نشغل أبدا ....

Practical part ⇒

① (τ-ω) Curve →

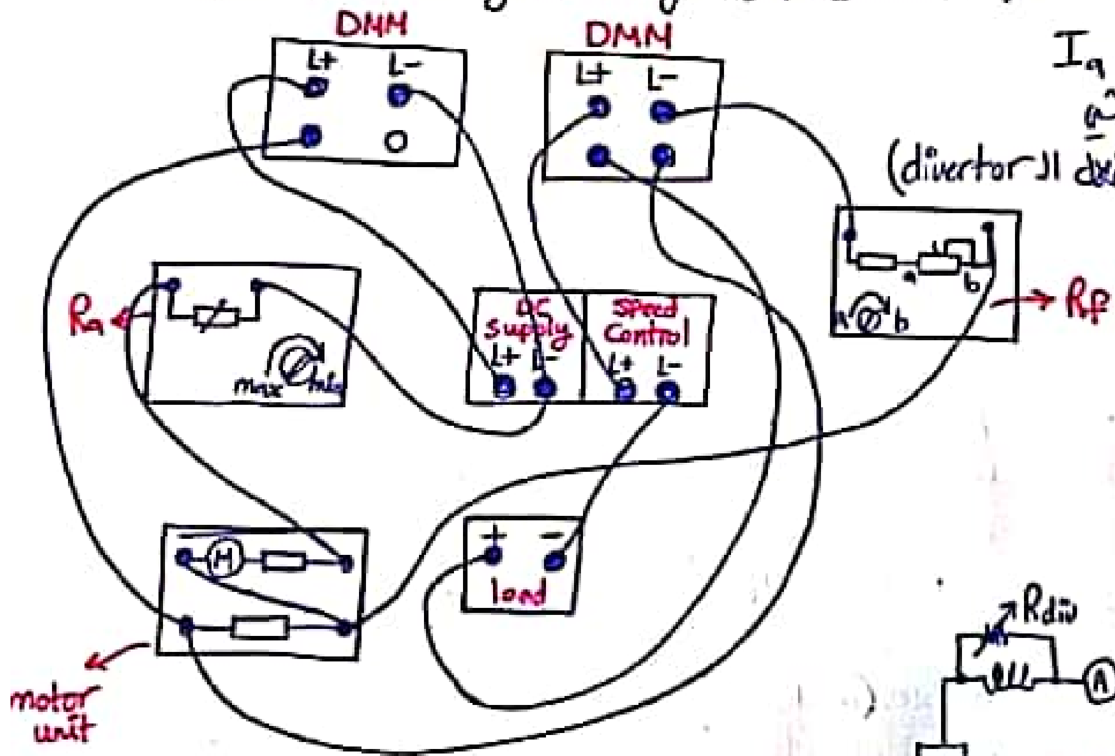


* تيار البدء والفولتية المطبقة على ال Series أعلى من ال shunt
* مع نقصان $R_{adj}\downarrow$ ، تزداد ω
* عند زيادة اللود تقل ω ⟶ $(\uparrow \tau,\ \uparrow I_a, \Phi, I_f)$

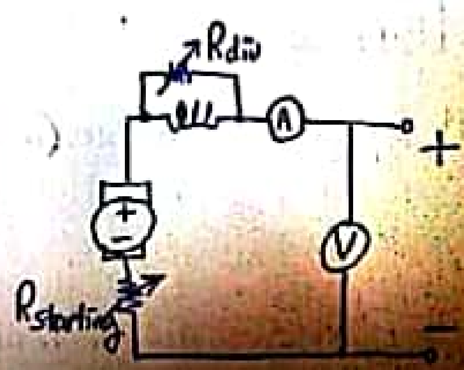
② Speed control by changing (V_T) →

بزيادة V_T تزداد معها السرعة والعكس

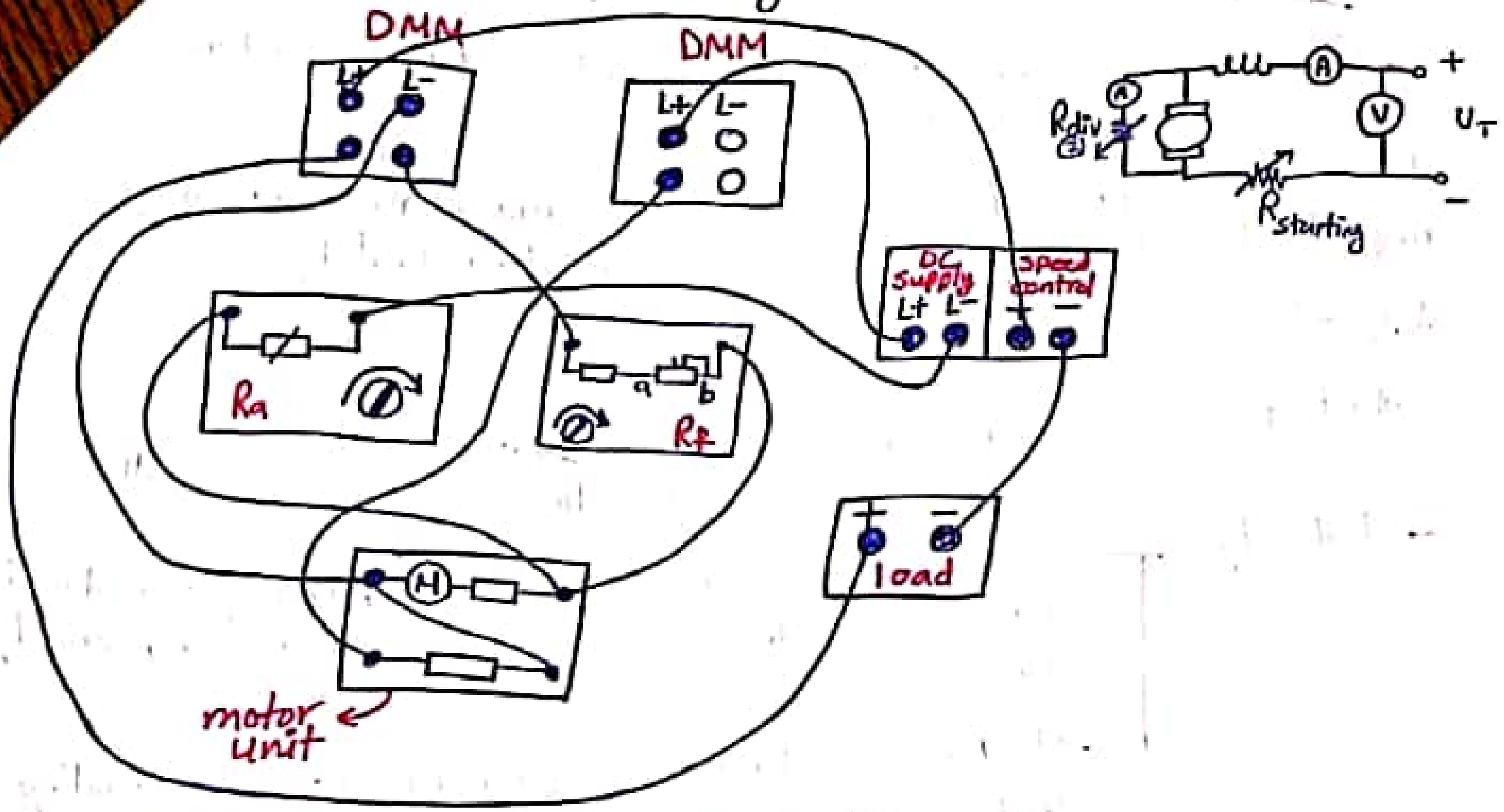
③ Speed control by shunting the field CCT →



بغيّر اللود عشان I_a
و I_f ما بصير عليها شي
(بغيّر ال field من خلال ال divertor)
والعلاقة عكسية
بين ω مع R_{div}.



(4) Speed control by shunting the armature circuit →



For a given T_L, if ($I_a\downarrow$) then ($\phi\uparrow$), as [$T_a \propto I_a$], this will increase the current taken from supply ($I_T\uparrow$), ($\phi\uparrow$), ($\omega\downarrow$)

Quiz Questions

- The 2 ways of changing the I_a during series experiment are diverter & load.
- Increasing the flux in the series will ______ the I_a
- What is the flux control methods can be applied in our Lab.? divertor
- During this experiment, which resistor we used in start control?
  Starting Rheostat (R_a)
- State 2 methods of starting control in series dc motor?

Exp(5) Three Phase Induction Motors

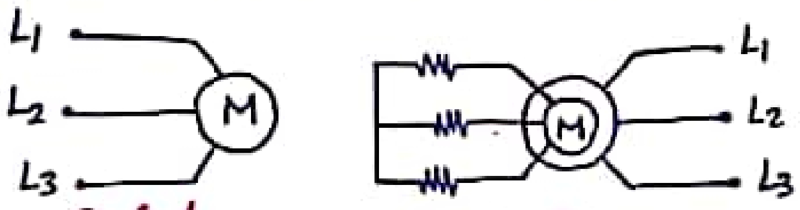
- It consists of → Stator, connected to a 3ϕ power system.
  → Rotor

due to the $\angle 120°$ phase shift between each successive phases, a rotating magnetic field is produced in speed that can be determined by:

سرعة المجال المغناطيسي الدوار ← $$n_{synch} = \frac{120f}{P}$$

which passes over the rotor bars and induces a voltage in them ولهالسبب منخبره induction motor.

- Rotor type → Squirrel cage, consists of a series of conducting bars laid into slots carved in the rotor face and shorted at either end by large shorting rings
  → Slip Ring "Wound Rotor", has a complete set of 3ϕ windings that are mirror images of the stator windings. Extra (R) can be added.



Squirrel Cage — Slip Ring

The Concept of Rotor Slip →

- The voltage induced in a rotor bar of an induction motor depends on the speed of the rotor relative to the magnetic fields.

$$n_{slip} = n_{sync} - n_m$$

n_m → rotor speed; n_{sync} → stator speed

if $n_m = n_{sync} \rightarrow slip = \emptyset$
$n_m = \emptyset \rightarrow slip = 1$

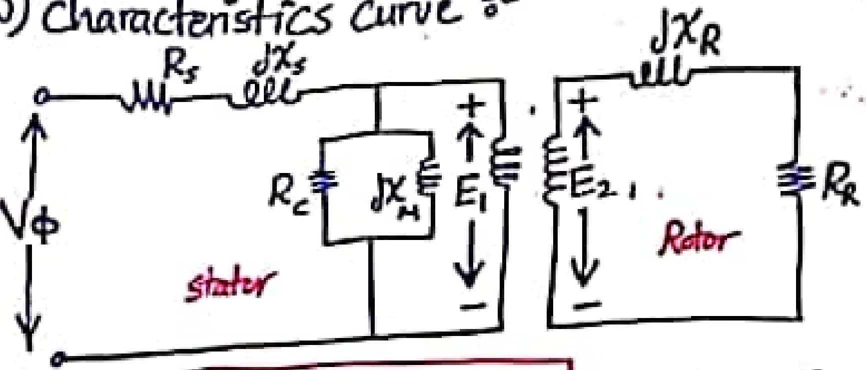
$$n_m = (1-S)\,n_{sync}$$

$$Slip = \frac{n_{slip}}{n_{sync}} * 100\%$$

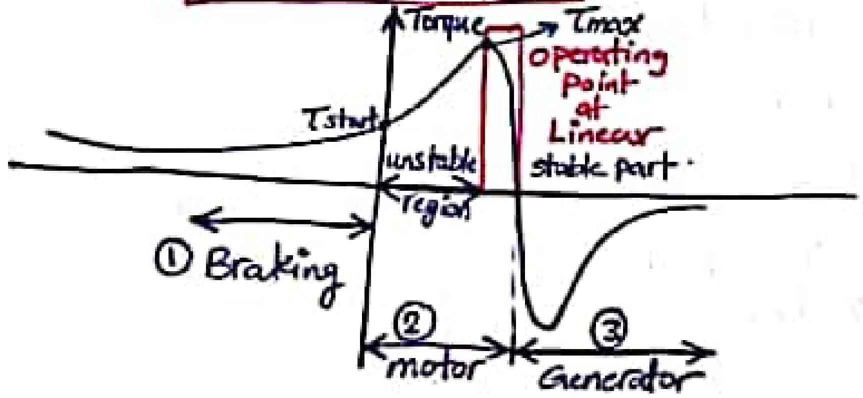
- Induction motor works by inducing voltages and currents in the machine rotor
- If the rotor is locked, so it will have the same frequency as the stator

$$f_{rotor} = S\,f_{stator}$$

(τ-ω) characteristics curve :



$$\tau = k s E_2^2 \frac{R_2}{\sqrt{R_2^2 + (sX_2)^2}} \quad , \quad k = \frac{3}{2\pi n_{sync}}$$



Operating Regions

① Braking "Plugging" → $n_m < 0$, $slip > 1$, torque is (+ve) while speed is (-ve)

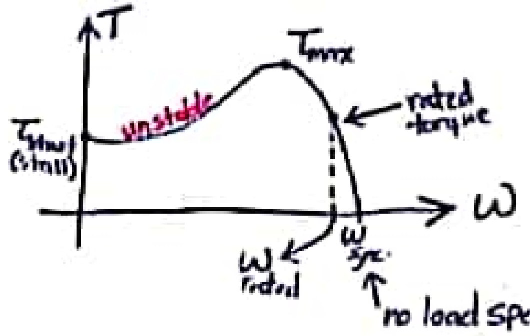
this mode of operation can be used to quickly stop a machine, by switchi[ng] two phases which causes the result of changing the direction of motion of the stator magnetic field.

② Motoring → $0 < n_m < n_{sync.}$, $0 < slip < 1$, torque and motion are in the same direction

the most common mode of operation.

③ Generating → $n_m > n_{sync}$, $slip < 0$, torque is (+ve) while speed is (-ve)

Unlike plugging, if the power converted is (-ve), so is the air gap power.



- at no load, the IM operates at ω_{sync}
- as the load increases (due to bearing & load friction), the machine slows down
- If the motor is overloaded, it will reach to the max. torque

---

Practical part ⇒ باللاب استخدمنا (Squirrel cage) طالع منه ٣ أطراف

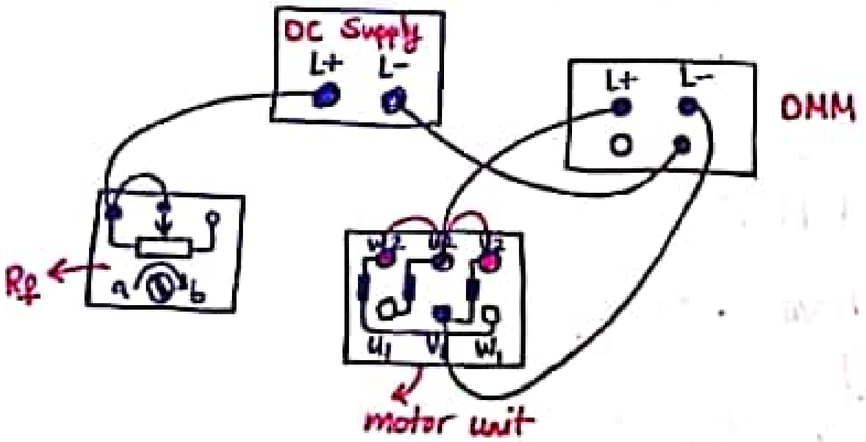
Three tests are used to determine the parameters of the induction motor model:

1] DC test: بنطبق (dc voltage) عال stator ونزيد فيه لحد ما يمر ال (I_{rated}) بدون ما يتجاوز

by applying a variable dc voltage to two terminals of the stator winding that should be increased so that the current flowing in the stator winding reaches the rated current.

$$R_s|_{delta} = \frac{3}{2}\frac{V_{DC}}{I_{DC}}$$ ← V_{DC}: V_{rated}, I_{DC}: I_{rated} — منقدر نعرف قيمة (R_s)

$$R_s|_{star} = \frac{1}{2}\frac{V_{DC}}{I_{DC}}$$



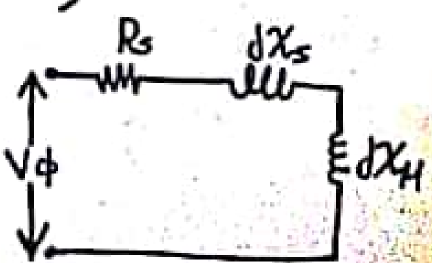
2] No Load test: This test is carried out with a delta connected stator.

during this test, IM operates as motor and run at ω_{sync} (slip → ∅). Therefore, all P_{in} will be consumed as losses: stator copper losses ($I_\phi^2 R_s$)

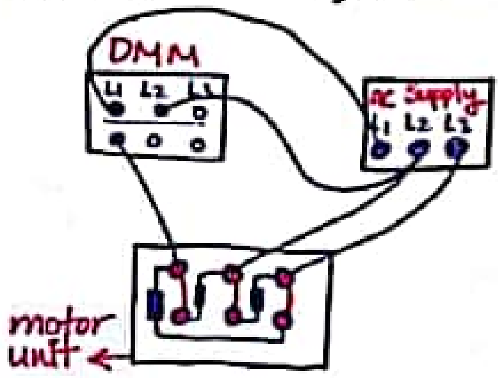
core losses & mechanical rotational losses (friction and windage loses).

$$P_{rot} = P_{in,NL} - P_{cu,s}$$
$$= P_{in,NL} - 3I_\phi^2 R_s$$

$$X_M = \frac{V_\phi}{I_\phi}\sin\theta - X_s$$



Connecting the motor (stator) in delta:



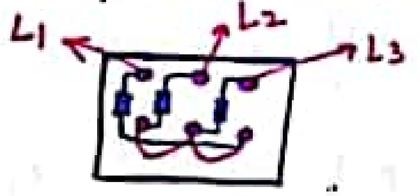
3] Locked Rotor Test:

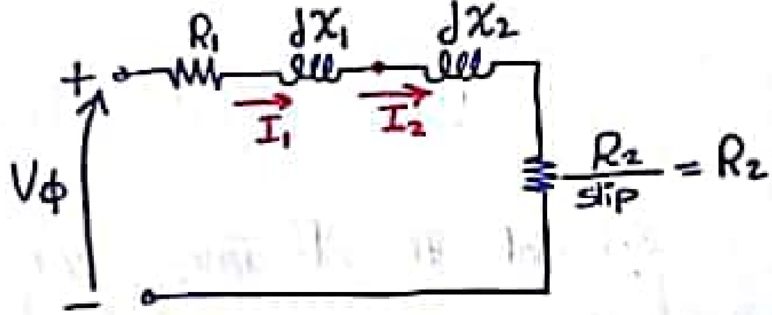
by applying low voltage on the stator terminals (motor unit) so that the rotor doesn't rotate and its speed becomes zero and full load current passes through the stator winding.

(لو كانت الفولتية المطبقة عالية هالشي هيسبب يعني تلف ع ملفات ال stator)

then, slowly increasing the voltage in the stator winding so that current reaches to its rated value.

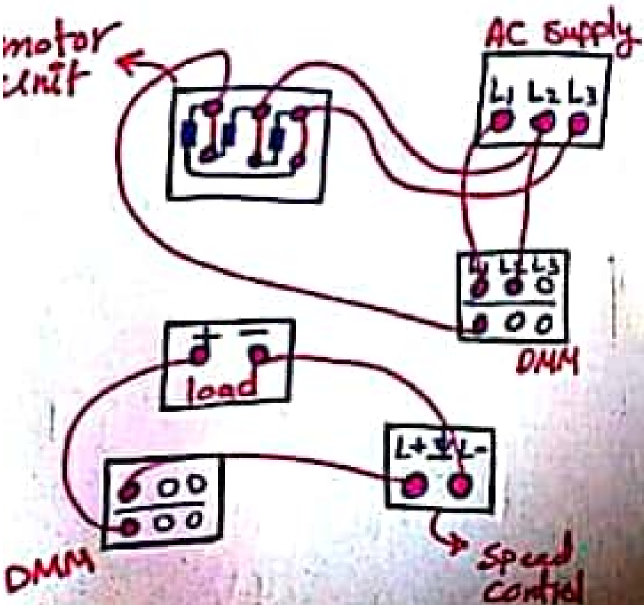
نفس تشبيكة الاختبار أعلاه بس ال motor unit مشبوكة ع star

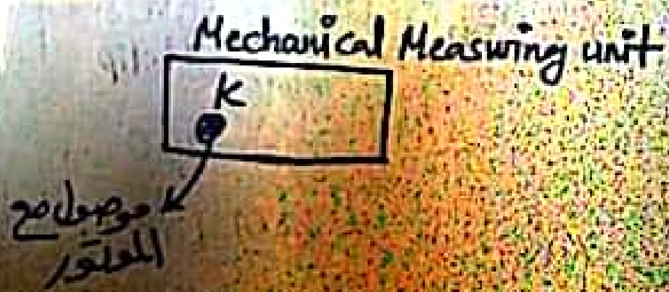




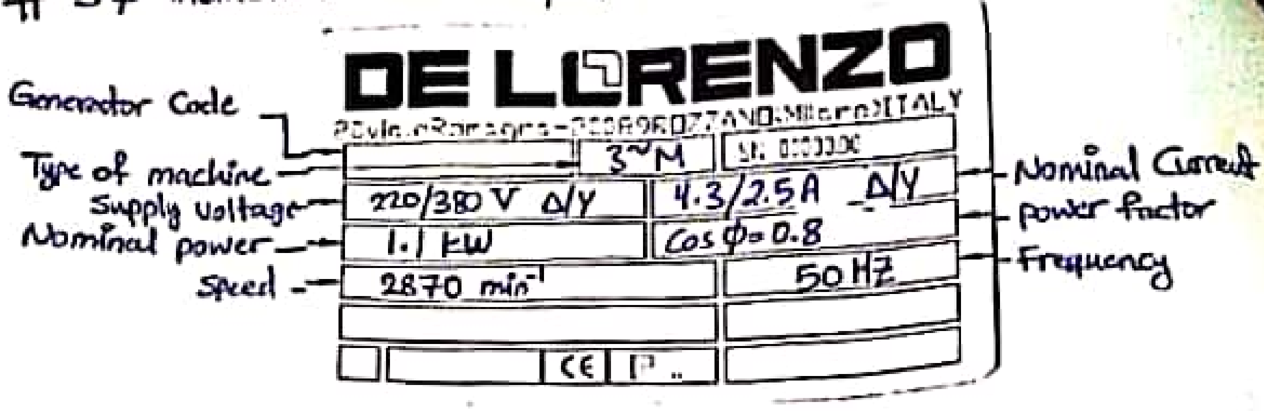
4] Load Test: to study (τ−ω) curve of the IM and its efficiency

بحيث ع نفس الفولتية المطبقة (220V) مثلاً
لنوصل لل rated τ_{load} ، بنغيّر ع اللود
ونشوف شو بصير على السرعة





3φ induction motor nameplate :



Q1 From the above nameplate, answer the following :- [If the motor have 2 poles, rated slip = 0.05]

1.) Calculate the synchronous speed ?

$$n_{sync} = \frac{120f}{P} = \frac{120(50)}{2} = 3000$$

2.) Calculate the input power ?

$$P_{in} = \sqrt{3}\, V_L I_L \cos\theta = \sqrt{3}(220)(4.3)(0.8) = 1311 \text{ W}$$

ولو أخذة قيم $V_L = 380$ V ، $I_L = 2.5$ A ← ميطلع نفس الجواب تقريبًا

3.) Calc. the efficiency ?

$$\%\eta = \frac{P_{out}}{P_{in}} = \frac{1100}{1311} \times 100 = 83.9\%$$

4) Calculate the motor speed (n_m) ? (mechanical)

$$n_{slip} = n_{syn} - n_m$$

$$slip = \frac{n_{slip}}{n_{sync}} \Rightarrow n_{slip} = (0.05)(3000) = 150 \,[rpm]$$

$$\therefore n_m = n_{sync} - n_{slip} = 3000 - 150 = 2850 \,[rpm]$$

#

Q2 For the no load test, $R_s = 8.5\ \Omega$

V_{L-L}	I_L	P_{tot}	N_m [rpm]
220 V	2.45 A	152 W	2989

Find P_{tot} ?

$$P_{tot} = P_{nl} - 3 I_\phi^2 R_s$$

$$= 152 - 3 \frac{(2.45)^2}{(\sqrt{3})^2}(8.5)$$

$$= 100.98\ W \quad \#$$