تقدم لجنة ElCoM الاكاديمية

دفتر لمادة:

آلات كهربائية

جزيل الشكر للطالبة:

لجين ابو غزالة

ELECTRICAL MACHINERY

8-6-2014 , 9-6- 2014 شيت
12-7-2014

2.9 → self study

No.

1 Introduction to machinery Principles

1.1 Electrical Machines transformers and daily life.

electrical machine: is a device that convert mechanical energy to electrical energy or electrical energy to mechanical energy.

* motor → convert electrical energy to mechanical energy.
* generator → convert mechanical energy to electrical energy.

when an electrical machine can convert Power in either direction it can be used either a generator or a motor.

مبدأ عمله → it convert energy from one form to another due to the action of magnetic field [هي بتحول من شكل لآخر باختلاف]

* transformer → convert electrical energy at one level to another level. it ~~work~~ operates on the same ~~way~~ principle as motor and generator due to the action of the magnetic field.

* Why electrical ~~or~~ motor and generator are common?? ~~Kra~~
Power is clean and electrical efficiency is easly to transmit over long distance and easly to control, dose not required fuel . وبنقدر نولد الطاقة الميكانيكية بمكان
دعوها ونعمل بعيد منقلها , ال transformer aid ال losses ال ويبتقل الطاقة بتقلل

أول استخدام لل transformer

V1

No.

1.3 Rotational motion , Newton's Law and Power Relations: —

→ All electrical machine rotate about an axis is called the shaft of the machine.

مقيد

machine normally turn on a fixed shaft. so their rotation is restricted to one angular dimension. Relative to the given end of the machine shaft the rotation can be

CCW (counterclockwise) → positive.

CW (clockwise) → negative.

The major concept of angular motion :—

[1] Angular Position θ measured from a referance point in degree or radian. (personal or random.)

[2] Angular velocity ω is the rate of change in angular position with respect to time. $\boxed{\omega = \frac{d\theta}{dt}}$

ω → + CCW →

ω → − CW

θ → radian → radian / secound. — m → it indicates a mechanical quantities

ω_m → angular velocity expressed in radian/sec

f_m → angular velocity expressed in revolutions/sec

n_m → angular velocity expressed in revolution/min

$$\boxed{\begin{aligned} n_m &= 60 f_m \quad \text{---} * \\ f_m &= \frac{\omega_m}{2\pi} \quad \text{...} * \end{aligned}}$$

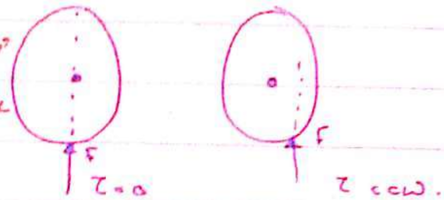
$$\boxed{n_m = \frac{60\,\omega_m}{2\pi}}$$ ← اهم قاعدة

No.

[3] Angular acceleration ⌒ its the rate la change in velocity in respect to time.
→ + if the angular speed is incresing in an algebric sense

$$\boxed{\alpha = \frac{d\omega}{dt}}$$ onit is radian/ sec^2.

لانوا ما بكون في قوة ع التلاقي بتتداخل القوه مع نقطة الدوران.



Torque τ
→ Force to rotate an object about an axis.
→ Force applied to an object cause it velocity to change. when absence of force the veloity is constant, the more force is applied to more repidly velocity change. the same when object is rotating the angular speed is constant when a torque is more the more repidly the angular velocity change. [it is depended on the magnitude at applied force and the distance between the [axis of rotation and the line of the action force]]

→ the tourge is the product of the force applied to the object and the smallest distance between the line of the action force and the object's axis of rotation.

$\tau = rF \sin\theta.$ ↳ angle between vector r and vector F. العامودي

طول الذراع

Newtons law of Rotation $F = ma$ → m/s^2 / feet/s^2

Newton, pounds — kilograms, slugs

moment of initia [kilograms - meter^2 or slug - feet^2]

$\tau = J\alpha$ → angular of acceleration [rad/s]

net applied tourge [feet pound - feet]

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No.

Work ~~to~~ application of force through a distance.

$W = \int F dr$ $W = \int T d\theta$

Jolues or foot-pound.

$W = Fr$ $W = T\theta$ work Rotational.

Power rate of ~~doi~~ doing word

$P = \frac{dW}{dt} = Fv$ [Power] watts hourse power

velocity foot-pound / second.

$P_{torque} = T\omega$.

velocity

$\boxed{\text{power hourse} = 746\ kW}$

$\boxed{1\ KW = 1.34\ hp}$

1.4 The Magnatic Field:

تيار يعمل مجال مغناطيسي بالمنطقة حوله

2. time changing magnatic field indues a voltage coil of wire if it passes throught that coil [This is the transformer action]. $emf = -\frac{d\phi}{dt}$ ، اذا كان بدارة مغلقة بولد تيار

3. A current - carryying wire in the presence of magnatic field has a force induce on it [This is the basis of motor action]. $F = (\vec{I} \times \vec{B}) l$

4. A moving wire in the presence of magnatic field has a voltage induced in it [This is the basis of generator action]. $\vec{E} = (\vec{v} \times \vec{B}) l$

، اذا كان بدارة مغلقة بولد تيار

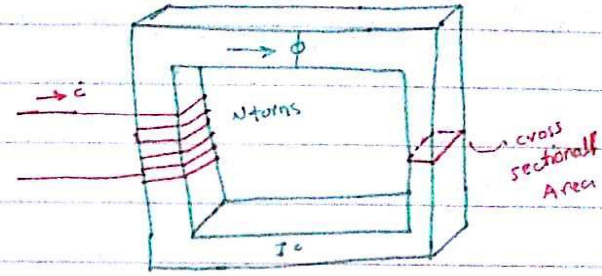
No.

Production of magnatic field:

$$\oint H \cdot dI = I_{Net}$$

H → magnatic filed intensity

dI → length



premeabilty of matrials μ

$H I_c = N i$ $\quad H = \dfrac{N i}{I_c}$ $\quad B = \mu H$

B → magnatic flux density

magnatic motive force $= N \; I$

N → عدد اللفات ، I → بالتيار

ينشأ تدفق مغناطيسي (ϕ)

نتيجة مرور التيار في ~~الملف~~ المادة تنشأ ϕ ج mmf

التسخينه

لكامپوحب لية الصين

$$\phi = \frac{mmf}{R}$$

R (Relactance) $= \dfrac{L}{\mu A}$ $\quad L$ → الطول $\quad$ [A. turns. / wp]

~~النفاذية المغناطيسية~~ لها

A → المساحة

μ → permability

A. turns $\times \frac{H}{m}$ / m

A-times

A. turns . H^{-1}

magnatic Field strength [intensity]: $H = mmf / L$ $\quad$ [A/m]

magnatic Flux density $= B = H \cdot \mu$ $\quad$ [T تسلا] [wp/m²]

Flux $= B \cdot A$ $\quad$ [wp] $\quad$ if flux density constant, $B \perp A$

μ [permability] $= \mu_{relative} \cdot \mu_{air}$ $\quad$ [Heres / m]

$\mu_{relative}$ → relative permability

μ_{air} → $4\pi \times 10^{-7}$ → permeability of free space

No.

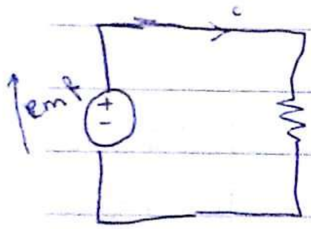
If we say that the steel has a ~~perar~~ permeability of 2000 to 6000 (2000 to 6000 time) or more more flux is establisied in apiece of steel than an corresponding area of air.

وكل ما زاد ~~المقاومة~~ النفاذية لمادة بكون ال~~فيلو~~ flux كبير فيها اكبر

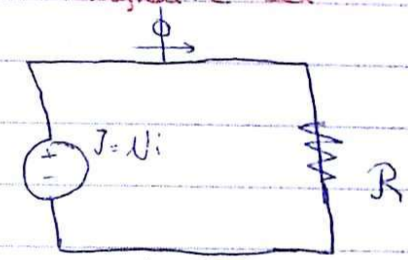
فالحديد أكبر من نفاذية الهوا عشان هيك معظم الـ flux بمشي جوا والكسائر بتكون اقل

فاختيار المادة شكل عامل رئيسي بزيادة او تقليل المجال داخل الملف (core)

Electrical cct



magnetic cct



$I = \frac{V}{R}$ ينشأ تيار يقاس

التيار هو تدفق للالكترونات

$\phi = \frac{J}{\mathcal{R}}$

الناشئة من مرور التيار في الـ inductor/ $J(mmf) = Ni$ [Ampere.turns]

$P(\text{permeance}) = \frac{1}{\mathcal{R}}$

$\phi = Ni\,P$

* Relactance obey the same rule of resistance

parallel Relactance $= \frac{1}{\mathcal{R}_1} + \frac{1}{\mathcal{R}_2} + \frac{1}{\mathcal{R}_3} \dots$

series combination $= \mathcal{R}_1 + \mathcal{R}_2 + \mathcal{R}_3 \dots$

* permenance obey the same Rule of conductances.

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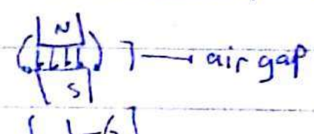
بعض ملاحظات :

1 small flux escapes from the core into surrounding air -low Permability- -1 this flux called lankage flux. [1-6]



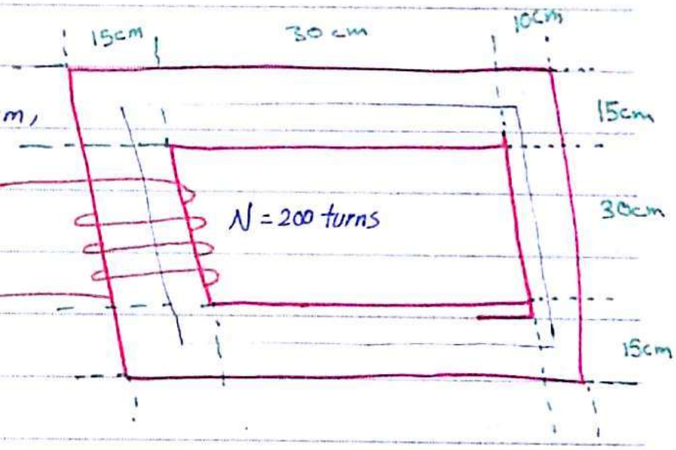
[1-6]

2 - If there is air gaps in the flux path in a core. the effective cross sectionall area of the flux (airgap) is bigger than the cross sectionall area of the iron core

it cause by th ~~e~~ fringing effect at the magnetic flux [1-6]

Example 1-1

the depth of the core (into the page) is 10 cm, 200 turns it wrapped arround left side $\mu_r = 2500$. how much flux produced by 1-A input current ??



Solution :

$\phi = \dfrac{Ni}{R}$ [illegible]

$L_1 = \dfrac{15}{2} + 30 + \dfrac{15}{2} = 0.45\,m$ التيار بيمشي بالنص

$A_1 = 10 \times 10 = 0.01\ m^2$

$R_1 = \dfrac{L_1}{\mu A_1} = \dfrac{0.45}{2500 \times 4\pi \times 10^{-7} \times 0.01} = 14323.94\ A.turns/wb$

$L_2 = (\frac{15}{2} + \frac{10}{2} + 30) \times 2 + 45 = 130cm = 1.3\ m$

$A_2 = 15 \times 10 = 0.015\ m^2$

$R_2 = \dfrac{1.3}{0.015 \times 2500 \times 4\pi \times 10^{-7}} = 27586.8568\ A.turns/wb$

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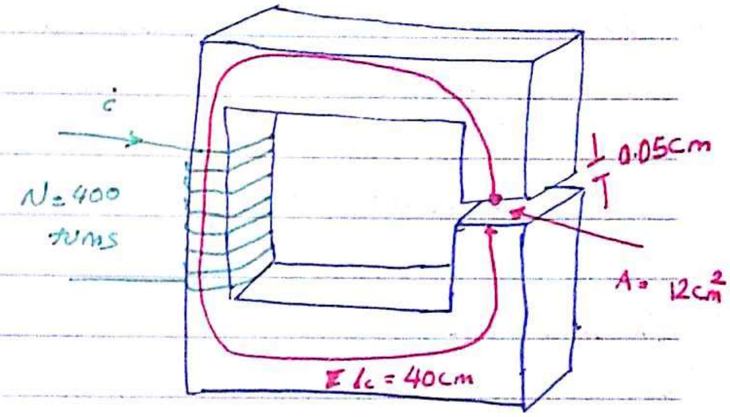
$R = R_1 + R_2 = 41910.7968$

$$\phi = \frac{1 \times 200}{41910.7968} = 4.772 \times 10^{-3}\ wb$$

Example 1-2:



mean path length 40cm, there are a small gap of 0.05cm. The cross sectionall Area of the core is 12 cm², the relative ~~perm~~ perambility is 4000 and the coil of wire has turn 400.

Assume that ~~B~~ fringing in the air gap incresses the effective cross sectionl area of the air gap by 5 percent.

a) total reluctance of the flux

b) the current to produce a flux density of 0.5T in the air gap.

solution:

$R = \frac{L}{\mu A}$ $\qquad \phi = \frac{Ni}{R}$

$R_{core} = \frac{0.4}{4000 \times 4\pi \times 10^{-7} \times 12 \times 10^{-4}} = 66314.55962$ A.turns/wb

$R_{air} = \frac{0.05 \times 10^{-2}}{4\pi \times 10^{-7} \times [A]}$ $\qquad A = \left[12 \times 10^{-4} \times \frac{5}{100}\right] + 12 \times 10^{-4} = 1.26 \times 10^{-3}$

$= 315783.6172$ A.turns/wb

$R = 382098.1769$ A.turns/wb

No.

$$\phi = B.A$$

$$\phi = \frac{Ni}{R} \qquad \frac{Ni}{N} = \frac{B.A.R}{N}$$

$$I = \frac{B.A.R}{N} = \frac{0.5 * 1.26 \times 10^{-3} * 382098.1769}{400}$$

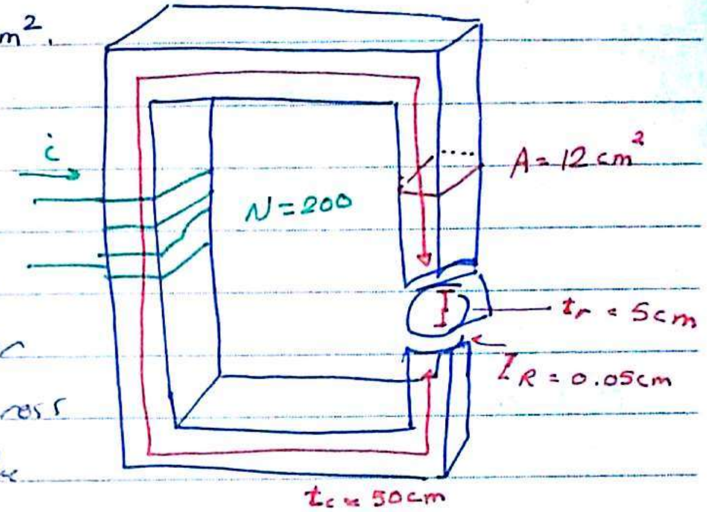
$$I = 0.6018 \text{ A}.$$

$$B = \mu \frac{Ni}{L}$$

$$\frac{0.5 * 0.05 \times 10^{-2}}{400 * [9000 \times 4\pi \times 10^{-7}]} = I$$

Example 1-3:

the mean pathat the stator is 50cm andcross sectional area is 12 cm^2. the mean path al the ~~stator~~ rotor is 5cm, and it cross sectional area also may be assumedto be 12cm^2. each air gap between the rotor and stator is 0.05cm wide and the cross sectional area is 14cm^2 al the air gap (including fringing)



$\mu = 2000$, $N = 200$turns, $I = 1A$, ϕ flux density in the air gap will be ??

solution:

$$R_S = \frac{0.5}{12\times10^{-4} * 2000\times4\pi\times10^{-7}} = 165786.3991 \text{ A.turns/wb}$$

$$R_r = \frac{0.05}{12\times10^{-4} * 2000\times4\pi\times10^{-7}} = 16578.63991 \text{ A.turns/wb}$$

$$R_{air} = \frac{0.05\times10^{-2}}{4\pi\times10^{-7} * 14\times10^{-4}} = 284205.2555 \text{ A.turns/wb}$$) $\times 2$

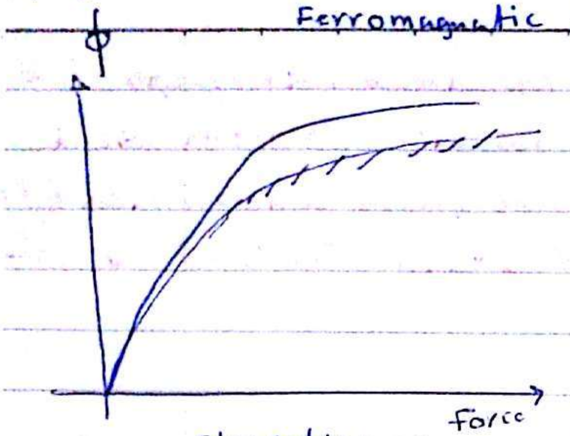
$$R = \cancel{466570.2945} \quad 750772.55$$

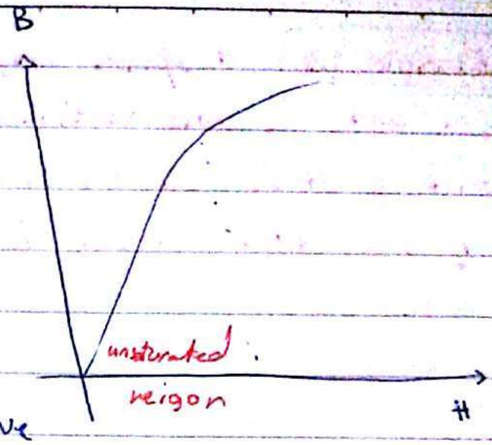
$$\phi = B.A$$

$$\frac{200(1)}{\cancel{466570.2945}\ 750772.55} = B * 14\times10^{-4} = \cancel{1.9\times10^{-3}} \quad 0.19$$

50 100 500 1000

Magnetic behavior for No.
Ferromagnatic Material.





stauration or magnetization curve

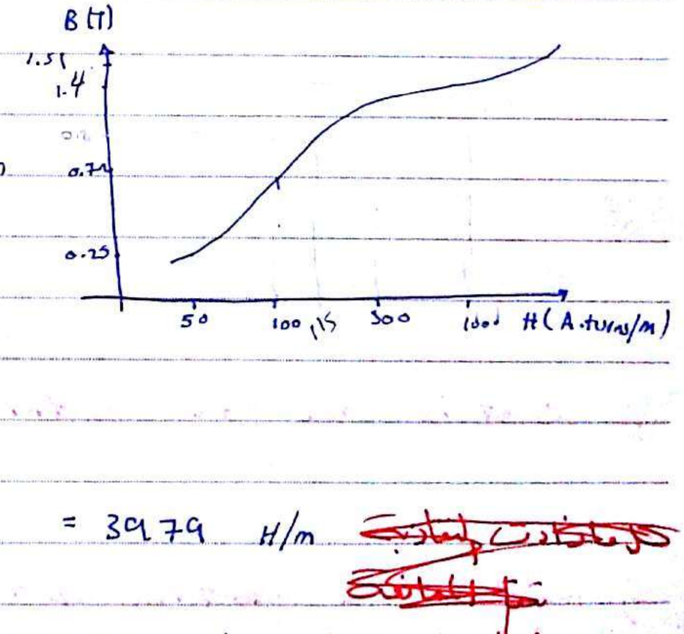
H propotional to $\mathcal{F}$ (for air يوجد فقط مستقيم) ϕ propotional to B

* أول الشيء التغير (H) قليلاً بحصل تغير كبير كذا يوصل لنقطة قبل saturated point بعد يصير التغير قليل
وبعد يوصل خطها بطل في تغير

in unsaturated region the premeability [slope] is constant

example:

Find Relative Permeability for
H = 50, 500, 100, 1000 A.turns/m



$\frac{B}{H} = \mu$ $\boxed{1}$ $\frac{}{50}$

$\mu = \frac{B}{H}$ $\mu_r = \frac{\mu}{\mu_0}$

$\mu = \frac{0.25}{50} = \frac{5 \times 10^{-3}}{4\pi \times 10^{-7}} = 3979$ H/m

$\mu_r = \frac{0.74}{100 \times 4\pi \times 10^{-7}}$ $\mu_r = 5730$ H/m كل ما زادت B ↑ تقل μ↓

$\mu_r = \frac{1.4}{500 \times 4\pi \times 10^{-7}} = 2228$ H/m

$\mu_r = \frac{1.51}{1000 \times 4\pi \times 10^{-7}} = 1202$ H/m

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Example 1.5 A square magnetic core has a mean path length of 55 cm and a cross sectional area of 150 cm^2. $N = 200$ turn coil of wire. μ is shown in the curve below [in the ~~prior~~ pre example]:

a] how much current is required to produce 0.012 wb of flux in the core

Solution

$$\phi = \frac{Ni}{R}$$ [illegible]

curve BH

$\phi = B.A$

$0.012 = B \times 0.015$ $\quad B = 0.8 \longrightarrow \quad H = 115$ A.turn/m

قابل

$B = H\mu \Rightarrow 6.956 \times 10^{-3}$ A/M

$\mu = \mu_r . \mu_0$

$$\phi = \frac{200\, i}{0.55} * 6.956 \times 10^{-3} * 0.015 = 0.316$$

b] what is the core relative permeability at that current

$$\mu_r = \frac{6.956 \times 10^{-3}}{4\pi \times 10^{-7}} = 5535 \ H/M$$

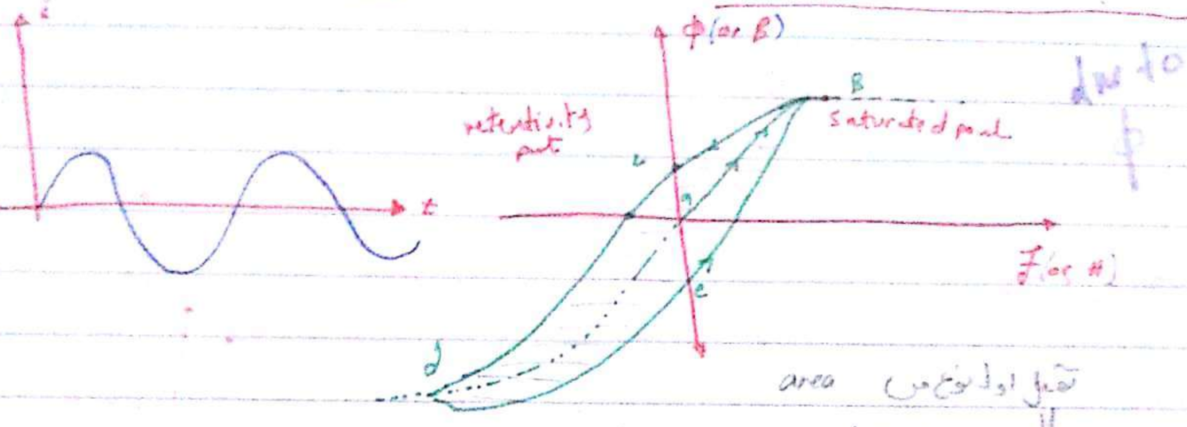
c] what is the reluctance of the core??

$$R = \frac{0.55}{6.956 \times 10^{-3} * 0.015} = 5271.22 \ A.turns/wb$$

Magnatic losses:

[1] hysteresis losses:

* ملاحظة: core على AC-current:



area تمثل او نوع من الـ losses

لما نزيد التيار بمشي بالمنحنى ab (saturation curve) ولما نقلل مابرجع على نقطة الصفر بمشي bcd ولما نرجع نزيده كمان مرة بيمشي deb

[hysteresis path bcdeb (cycle)

it happened because there is places called domain when mmf applied to it (بمشي مع اتجاه الـ) when mmf is removed not all domain will react it original (due to lack of energy) external energy used to help them called hysteresis losses

لانه بدنا large magnatomotive force بعدين نشاها الـ path abc (مابرجع عالصفر) برجع على نقطة اسمها retentivity

due to Voltage

[2] eddy current losses [نتيجة تغير Flux بنتج تيارات دائرية صغيرة (losses)]

لتجنبها نعمل الـ core على شكل صفائح نستعمل مادة عازلة او نزيد مقاومة المادة منعرف سليكون

[3] leakage flux [لانه الـ flux ما بيمشي بالـ core].

1.5 Faraday's law: [basis of transformers operation].

a time changing magnetic flux produce an electro motive force.

$$emf = -\frac{d\phi}{dt} * N$$

لهذا القوة تعاكس مجال المغناطيسي

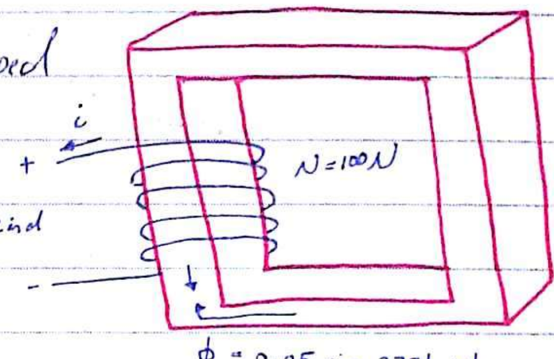
حسب lenz's law

Example: 1-6

it shows a coil of wire wrapped around an iron core. the flux is given by the equation

$\phi = 0.05 \sin 377t$ wb

$\boxed{N = 100}$, v_{eind}??



$\phi = 0.05 \sin 377t$ wb

of wat polarity is the voltage during the time when flux is increasing in the reference direction shown in the figure? (assume that the flux leakage is zero)

solution: $v_{eind} = N \frac{d\phi}{dt} = 100 \frac{d\, 0.05 \sin 377t}{dt}$

$100 \times 0.05 \cos 377t \times 377$

$v = 1885 \cos 337t$ v

الاتجاه حسب السؤال [التيار داخل من الموجب للسالب معناه عكس اتجاه ال ϕ

وموجب I عم V]

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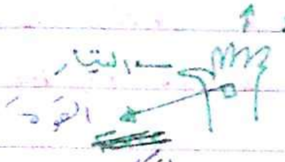
1.6 production of induced force on a wire: [basis of motor action]



أداة لتحديد الاتجاه

سلك يمر فيه تيار وموضوع في مجال مغناطيسي منتظم
ينشأ عليه قوة مقدارها

$F = i(I \times B)$.

i → current. I → length of wire. B → magnetic flux density.

$= i L B \sin\theta$

↳ wire flux density vector

Example 1.7 : The magnetic flux density is 0.25T directed in to the page if the wire is 1.0 m and carries 0.5 A . in direction from the top to the bottom F?? direction and magnitude [1.16]

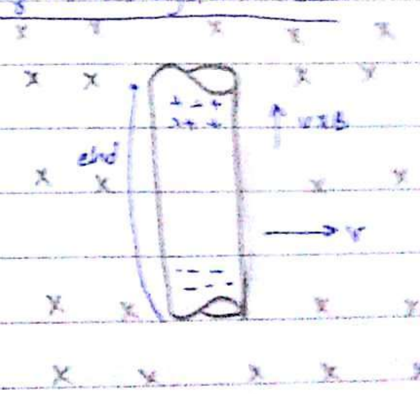
solution :

$F = i L B \sin\theta$

$0.5 * 1 * 0.25 \sin 90 = 0.125\ N$ to the right

1.7 Induced voltage on a conductor Moving in a Magnetic Field

a wire with the proper orientation moving through magnetic field a voltage is induced in it.



$v_{ind} = (v \times B) . I$ → length

v → velocity, B → density

[basis of generator action]

Example 1.8 : [illegible] Show an conductor moving $v = 5\,m/s$ to the right in the presence of a magnetic field. the flux density 0.5T into the page length of wire is 1m. What are the magnitude and polarity of the resulting induced voltage??

[illegible] I [illegible] (v x B) الزاوية بين

Solution: $V = (v \times B) \boxed{\cdot}\, r$

$(5 * 0.5 \sin 90) \cdot 1 = 2.5V$

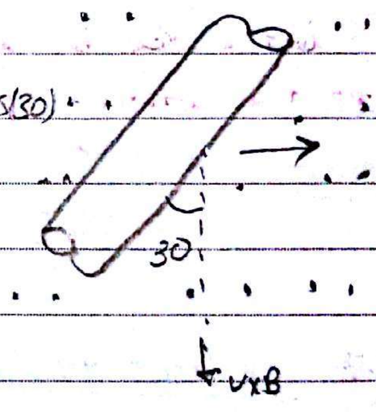
Example 1.9 conductor moving with velocity of 10m/s to the right in a magnetic field. the flux density is 0.5T, out of the page. and the wire is 1m length, orinted as shown. what is the magnitude and polarity of induced voltage?!

Solution:

$V = (10 * 0.5 \sin 90) * 1 \cos(30)$

$= 4.33$

[illegible]



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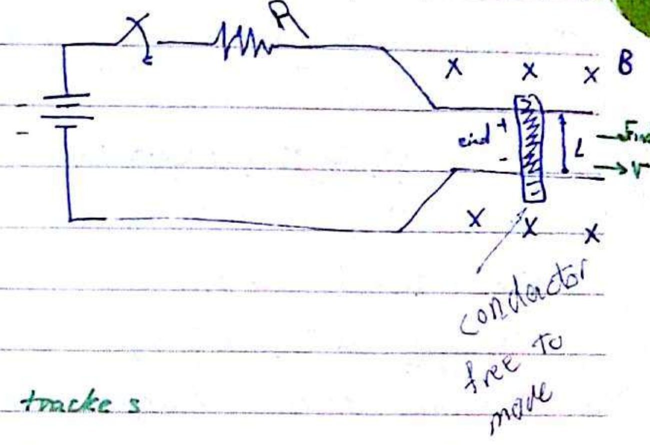
1.8 the linear DC - ~~Mot~~ Machine -



1. $F = i(l \times B)$
2. $e_{ind} = (V \times B) \cdot l$
3. kirchhofs voltage law for this is :

$$V_B = IR + V_{eind}$$

4. Newton's law for bar accross the trackes

$$F_{net} = ma$$

No loaded process:

* close the switch :

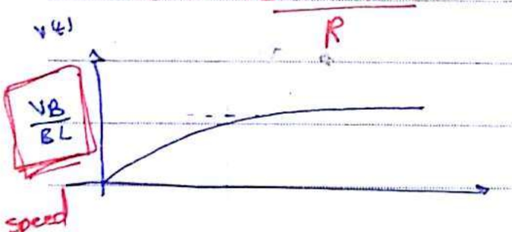
$$i = \frac{V_B - V_{eind}}{R} \qquad V_{eid} = 0 \qquad \boxed{i = \frac{V_B}{R}} \Leftarrow \text{at starting.}$$

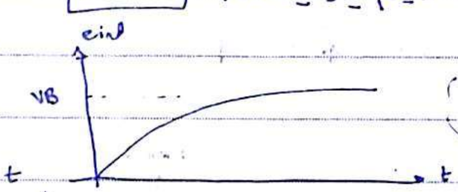
$F = ilB$ to the right للرسل — $e_{inds} = VB \cdot l$ الوجب ليحرك

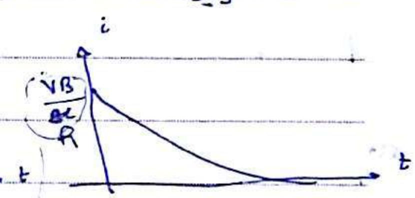
* after moving

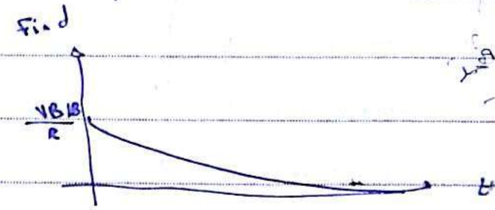
$$i = \frac{V_B - V_{eind}\uparrow}{R}$$

$\boxed{\Sigma F = 0}$ تولد الـ V_{einds} ويقل التيار ليحدث









مع مرور الزمن التوليد يزيد والتيار يقل والسرعة
حتى تصبح القوة $\Sigma F = 0$
والوصول لـ constant
steady-state speed.

بعد غلق المفتاح :-

١- التيار بيمشي وبتكون قيمته $i = \frac{V}{R}$

٢- مرور التيار داخل السلك في مجال مغناطيسي تتولد قوة $F = ilB \sin 90$ الموصل

٣- تخلي القوة يتحرك بعد ... متحرك V_{eind} = $VB \sin 90 \cos 0$ ليحرك

٤- وجود الـ V_{eind} يقلل التيار $I = \frac{V - V_{eind}}{R}$ وبالتالي induced Force يقل

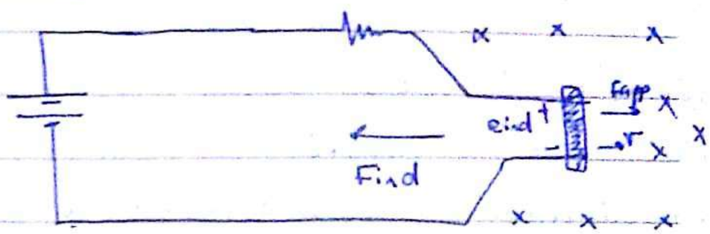
$$V_{ss} = \frac{V_B}{Bl} = \text{السرعة} \qquad F = 0 \qquad i = 0 \qquad \underline{e_{id} = V}$$

$V = VB \sin 90$

$$\frac{V_B}{Bl} = \frac{VBl}{Bl}$$

No.

The linear DC Machine as a motor: ~~Load~~



اذا كان في قوة خارجية ؟؟

Fload عكس اتجاه الحركة

$F_{net} = F_{load} - F_{ind}$

رح تتباطأ سرعة الـ Bar !!

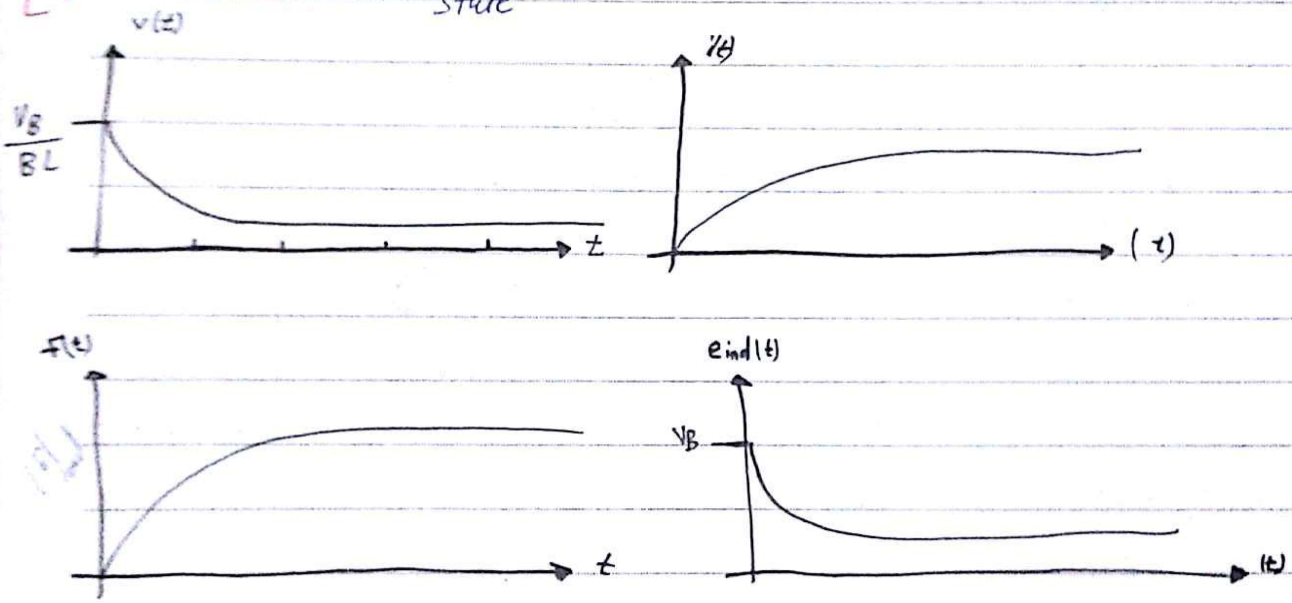
Loaded Process [وضع load يعيق الحركة].

حركة الـ Bar ↓ [يعني السرعة قلت] بالتالي e_{ind} بتقل ↓ $e = (v \times B) \cdot L$ ↓ ما انتقل التيار يزيد

$\uparrow i = \frac{V_B - V_{ind} \downarrow}{R}$

وبالتالي الـ F_{ind} رح تزيد [رح تضل تزيد حتى تساوي القوة الخارجية وتعاكسها بالاتجاه] steady state

[السلك بشعر انه بس يتحفز على القوة [Friction load



$F_{ind} = e_{ind} i = P_{conv.}$

$V_B = RI_a + V_{eind}$

$V_B = RI_a + [B\omega l]$ - مثلاً عاوزين الـ سرعة اتنا يقل

- اذا قلت الـ سرعة بسبب زيادة الحمل) بزيد التيار

No.

- summarize the behavior:

1- ~~can~~ a Force is applied in the opposite direction of the induced Force so net force is in the opposite direction and the bar is slow (acc is negative)

2- because the bar is slow the ~~e~~ voltage eind is decrese $i = V_B - V_{eind}$ ↑

3- Force induce $= L\,(i \times B)$ ↑ until $|F_{load}| = |F_{ind}|$

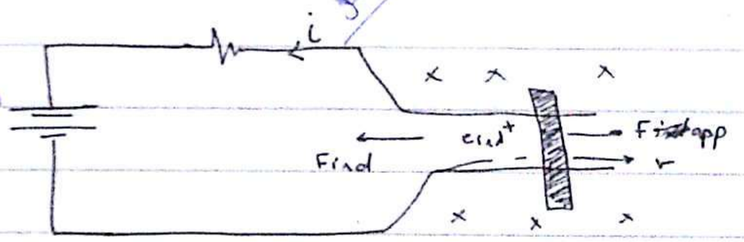
5- ammount of electrical power is equal to the ~~voltage~~ eind $\cdot$ i

~~mech~~ electrical Power now consummed to mechanical Power.

$\boxed{\text{Note}}$ Power from equation $= F_{ind}\, v$.

Real Power in Rotating motor $= \tau_{ind}\, \omega$.

The linear DC Machine as a Generator:



apply a Force in the direction of motion.

حركة الـ Bar ↑ (تسارع) باتجاه الحركة، السرعة بتزيد ↑، $e_{ind} = v\uparrow BL$، بتصير $V_B < V_{eind}$، التيار بعكس اتجاهه
ولقوة كمان $\xleftarrow{F_{ind}}$ حق تصير $F_{app} = F_{ind}$ opposite، والبطارية بتنشحن.

summarize:

1- Fapp is directed in the direction of motion, Fnet is the direction of motion

2- acceleration $a = \frac{F_{net}}{m}$ postive, v ↑

3- the voltage $e_{ind} = v\uparrow B$ so, $i = \frac{e_{ind} - V_B}{R}$ ↑

4- the $F_{ind} = i\uparrow B$ increase untile $|F_{app}| = |F_{ind}|$

5- the amout of mechanical Power equal to $F_{ind} v$ now conventing to electrical Power.

$$P = \tau_{ind}\, \omega$$

No.

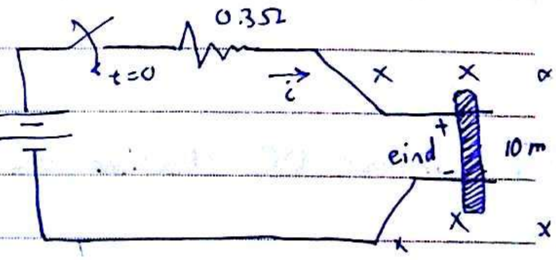
$e_{ind} > V_B \rightarrow$ act generator. [move rapidly]

$e_{ind} < V_B \rightarrow$ act motor. [move slowly]

سواء كانت motor or ~~gen~~ generator ← بتتحرك بنفس الاتجاه

مشكلة الموتور او generator ← انو التيار اول ما يدخل بكون كتير كبير وهاد بسبب مشاكل عشان هيك بضيفو add another resistance at starting

Example 1-10 a linear DC-Machine has a battery voltage 120V, an internal resistance 0.3Ω and a magnetic flux density at 0.1 T



$\boxed{1}$ what is the machine maximum starting current?? what is steady state velocity at no load??

KVL $\rightarrow$ $\frac{120}{0.3} = 400A$

~~[illegible] (v B l) = [illegible] m/s~~

steady state = $V_{ss} = \frac{V_B}{Bl} = \frac{120}{0.1 * 10} = 120\,m/s$

$\boxed{2}$ suppose 30N-force pointing to the right were applied to the bar. V_{ss}?? How much Power whould the bar be Producing or consumming? How much Power whould the battery be producing or consuming?

القوة بنفس اتجاه الحركة

No.

$e_{ind} = vBL$

$i = \frac{e_{ind} - VB}{R}$

$iR + VB = e_{ind} \rightarrow \boxed{iR + VB = vBL}$ — (1)

$F_{app} = F_{ind} = iBL$

$30 = i \times 0.1 \times 10 \quad \boxed{i = 30A}$

$30[0.3] + 120 = v^{s} \times 0.1 \times 10$

$v^{s} = 129 \, m/s.$

The Bar is producing power $\quad P = \cancel{VI} \overset{FW}{} = 129 \times 30 = 3870 \, W$

لانو generator بحول ميكانيك لكهربا

the Battery is consumming power $\quad P = V^{s} I = 120 \times 30 = 3600 \, W$

[3] 30N of force pointing to the left were applied to the Bar. Vss generator or motor??

motor

عكس اتجاه الحركة

at the steady state $|F_{app}| = |F_{ind}| = LBi$

$30 = 0.1 \times 10 \, i \quad \boxed{i = 30A}$

$e_{ind} = vBL$

at steady state $\frac{VB - e_{ind}}{R} = i \qquad -e_{ind} = Ri + VB$

$e_{ind} = -Ri + VB$

$120 - 30(0.3) = v^{s} \times 10 \times 0.1 \qquad v^{s} = 111 \, m/s$

Scanned by CamScanner

4. Assume a Force is Pointing ~~#~~ to the left is ~~and~~ applied to the bar. calculate the speed at 0N, 50N, 10N

$\sqrt{}$ 120 $\quad$ $\sqrt{}$ 135 $\quad$ $\sqrt{}$ 123

5. Assume the bar is unloaded and it suddenly runs into region where the magnetic field is weaked to 0.08 T. How fast will the bar go now?

$e_{ind} = V_b\ 0.08 \times 10$

$F = iBL$

$\boxed{0 = i = 0}$ $\qquad i = \frac{V_B - V_{ind}}{R}$ $\qquad V_B = V_{ind}$

$120 = V_b\ 0.8$ $\qquad V_b = 150\ m/s$

اذا عندي Friction ولما no load ال i ما بكون صفر بكون

$\frac{Friction}{LB} = i$

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No.

CHAPTER SEVEN:

DC MACHINERY FUNDAMENTAL.

7.1 A sample Rotating Loop between curved Pole face:

* Real generator and motor do not move in stright line is they **rotate**.

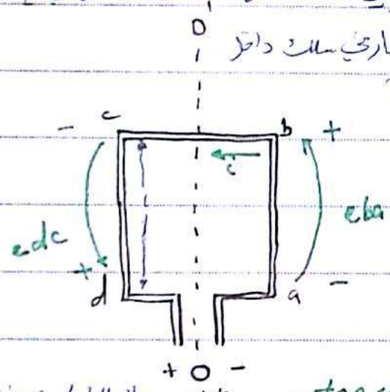
→ The rotating part at motor called **rotor**. Armature / عبارة عن اسلاك عم بلفها

→ The stationary part at motor called **stator** OR, field coil بتعطيني المجال Magnetic

the magnatic field is supplied by the North and south poles.

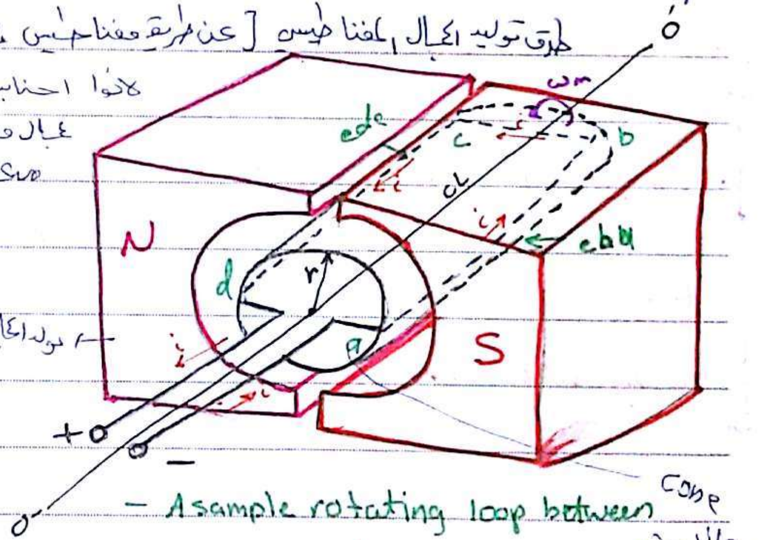
[طرق توليد المجال المغناطيسي [عن طريق مغناطيس مثل بالرسمة او عن طريق سلك عم بيمر تيار كهربائي]

لانو احنا بنعرف انو التيار المار في سلك داخل مجال مغناطيسي بولد حركة ميكانيكية



السلاك الي عم بيمر فيه التيار الكهربائي

— top view —

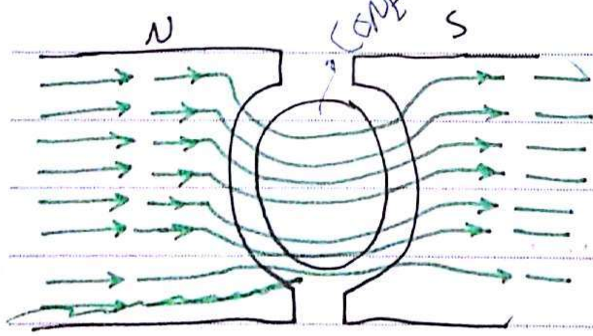


— A sample rotating loop between curved pole face.

cone عشان اكبر كمية من المجال

* عشان نقلل المسافة نحتاج سلك اقصر طويل بالهوا بين الـ pole والـ rotor وتكون خطوط المجال عامودية على سطح الـ rotor

[Reluctance & flux density] is uniform everywhere under the poles face



— view of field line —

- ab cd plane of عامودي على the page
- bc da parallel

No.

look at the drawing in pre page: ∞

The Voltage Induced in a Rotating Loop: → to determine the total voltage ccor on the loop examine each segment of the loop separatly and sum all resulting voltage the voltage on each segment is $e_{ind} = (V \times B) \cdot l$

$\boxed{\text{1 segment ab}}$:

$$e_{ba} = (V \times B) \cdot l = \begin{cases} VBl & \text{+ into the page} \quad \text{under the Pole face} \\ 0 & \text{beyond the pole edges} \end{cases}$$

$\boxed{\text{2. segment bc :}}$ $e_{cb} = 0$ $\underset{= zero}{\cos 90}$ لأن l عامودي على VxB

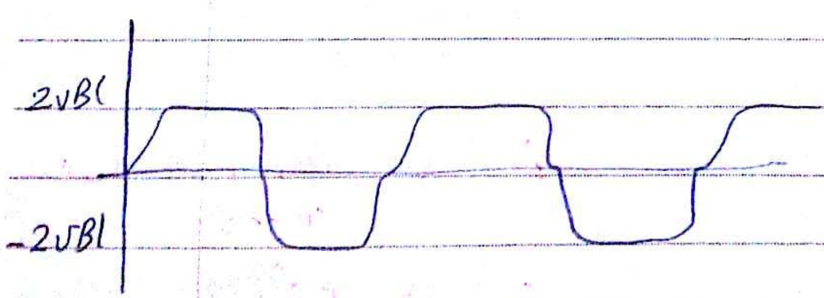
$\boxed{\text{3. segment cd :}}$

$$e_{dc} = \begin{cases} VBl & \text{+ out of the page} \quad \text{under the Pole face} \\ 0 & \text{beyond the pole edges} \end{cases}$$

$\boxed{\text{4. segment da}}$ $e_{ad} = 0$ نفس السبب في bc

$$\text{TOTAL } e_{ind} = \begin{cases} 2BVl & \text{under Poles Face} \\ 0 & \text{beyond the Pole edges} \end{cases}$$

The Output Voltage OF The Loop:



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No.

The final form at the voltage equation:

$$e_{ind} = \begin{cases} \frac{2}{\pi}\phi\,\omega n & \text{under the Pole face.} \\ 0 & \text{beyond the Pole edges.} \end{cases}$$

the voltage in any real machine will depend on the same three factors:

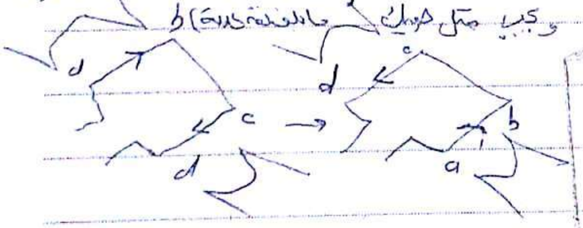
the flux, the speed of rotation, a constant representing the construction of the machine.

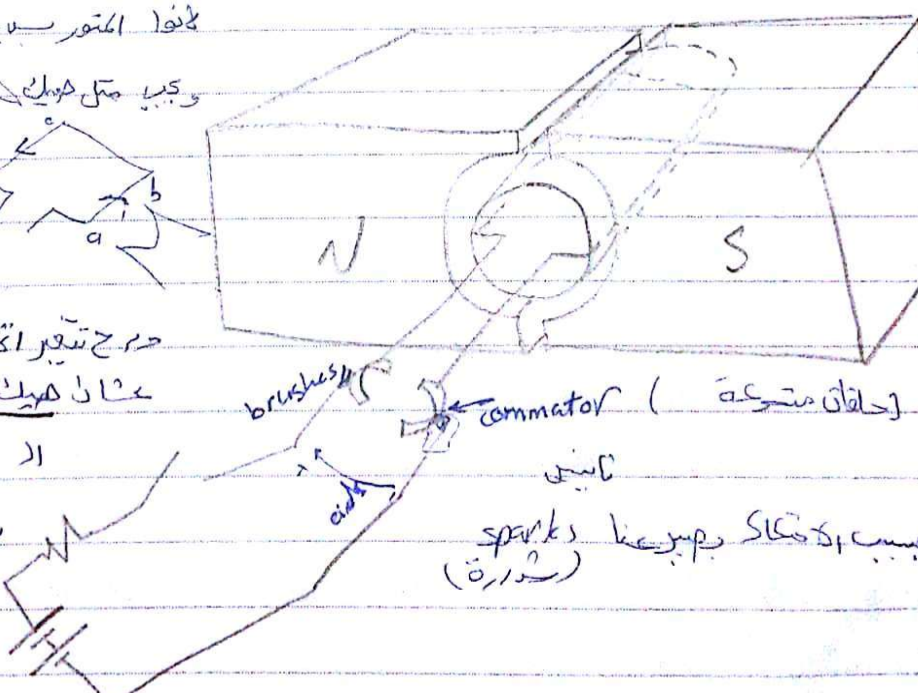
Getting DC - voltage out of the Rotating loop:

The loop give us alternately a constand negative and positive value how to get DC - voltage of it??

→ we add [commutator] at the end of the loop when the voltage change it direction the contact also switch connections so the output will build as the same way.

لانو المتور ساعي بس سلك ا ح يروح
وبيشوف قوة على الاسلاك اللي الاعلى
وكبيا مثل هيك بالمختصرة b)





رح تتغير اتجاه التيار تحت ال pole لو ما
عشان هيك بتكون AC ما بنريد

بين

* بسبب الاحتكاك بيصير عندنا sparks (شرارة)

ال commutator
بأمن انو ال اشارة الى فرا المولد
ما تتحرك م بالتالي التيار
تحت البولز دوما محافظ
على اتجاهه.

No.

اذا بدي المتور او ال generator يلف بالعكس بعكس الاقطاب او بعكس اتجاه التيار

The Induced Torque in the Rotating loop.

بالوصلة السابقة جبت بطارية كسب ال tourge بالعكس switch و مشي تيار ...

$F = (I \times B) l$

$\tau = F r \sin\theta$

→ ناخذ كل segment لحاله ونحسب

$\boxed{\tau = 0 \quad \text{beyond the pole edges}}$

1. Segment ab:

$F = iLB$

$\tau_{ab} = F(iLB)$ ccw

2. segment bc:

$F = 0$ $\quad l \parallel B$

$\tau_{bc} = 0$

3. Segment cd:

$F_{cd} = iLB$

$\tau_{cd} = riLB$ ccw

4. Segment da:

$F_{da} = 0$ $\quad l \parallel B$

$\tau_{da} = 0$

ToTal: $|\tau_{ind}| = \begin{cases} 2rBiL & \text{under the Poles surface} \\ 0 & \text{beyond the poles edges} \end{cases}$

$\phi = A_p B \qquad A_p = \pi r L$

OR $\tau_{ind} = \begin{cases} \frac{2}{\pi}\phi i & \text{under the poles surface} \\ 0 & \text{beyond the poles edges} \end{cases}$

the tourge in Any Real machine depend on:

the flux, the current, A constant Represent the constraction of the machine

Example 7-1. a simple rotating loop between curved pole faces connected to a battery and a resistor through a switch. the resistor shown models the total Resistance of the battery and the wire in the machine:

$r = 0.5m$ $\qquad l = \frac{1}{50} m$

$R = 0.3\Omega$ $\qquad B = 0.25T$

$V_B = 120V$

a) what happend when the switch closed??

solution: a current is produced $i = \frac{V_B}{R}$ ($V_{ind} = 0$)

$i = 400A$ → produced tourqe

$F = i(l \times B)$

$400 (1 \times 0.25$

$\tau = \frac{2}{\pi} \times 0.25 \times 400 = 63.66\ N.m$ CCW → بتتسارع

V_{ind} ← angular acceleration

$e_{ind} = \frac{2}{\pi} \cdot \phi \cdot \omega_n$

$V_{ind} = V_B$ ← $\tau = 0$ ← يقل التيار تقل التورك حتى يصير

شبه ال Linear motor

b) What is the machine maximum current, angular velocity steady state at no load ??

$i = \frac{V_B}{R} = 400A$ $\qquad A = 2\pi r l$

at no load: $V_B = V_{ind}$

$120 = \frac{2}{\pi} \times \phi \times \omega_n$ $\qquad \phi = \frac{Ni}{\mathcal{R}} = \frac{\mu i A}{l} = \frac{BA}{l}$

$\omega_n = 480$ $\qquad \frac{2}{\pi} \times \frac{B (2\pi r) l}{l}$

No.

c) suppose aload is attached to the loop, and the resulting load tourge is 10.N.m what would the new Vss? power by battery power by the shaft.

solution:

$\tau = \frac{2}{\pi} AB i$

$10 = \frac{2}{\pi} * B * \pi r L \, i \qquad i = \frac{10}{2 r L B} = \boxed{40A}$

$e_{ind} = \frac{2}{\pi} \phi \omega n$

$= \frac{2}{\pi} B \pi r L \omega n$

$e_{ind} = 2BrL\omega n$

$\therefore 40 = \frac{V_B - e_{ind}}{R} \qquad e_{ind} = 108$

$108 = 2(0.25) . 0.5 \times 1 \times \omega n \qquad \omega n = 432 \, rad/s$

$P = V I$

$= 120(40) = 4800$

$P = \tau \omega$ $\qquad$ $\boxed{motor}$

$\tau r \sin\theta * 432 = 4320$

$10 * 0.5$

d) suppose the machine is unloaded again torque of 7.5 N.m in the direction of rotation. Vss?? a machine or generator??

direction of motion τ ↑acc ↑speed eind ↑ current opposite

generator!!

$$\tau = \frac{2}{\pi} B \pi r L i \qquad i = \frac{7.5}{2*0.5*0.25} = 30A$$

$$30 = \frac{e_{ind} - V_B}{R} \qquad e_{ind} = 129V$$

$$129 = 2 B r L \omega n \qquad \omega n = 516 \text{ rad/s}$$

e) suppose the machine running unloaded, what should the final steady state speed of rotor be if the flux density were reduce to 0.2T.

$e_{ind} = V_B$

$$120 = 2 B r L \omega n$$

$$\omega n = \frac{120}{2 \times 0.2 * 0.5 \times 1} = 600 \text{ rad/s}.$$

$\downarrow \phi = N i \downarrow$

$i \downarrow \quad \omega \uparrow$

No.

التبادل

7.4 Problems With Commutation IN Real Machine:

1 - Armature ~~Reat~~ Reaction: ردة فعل المنتج

تعريفها → when a load is connected to the terminals of the machine a current will flow and produce a magnetic field of its own, which will distort the original magnetic field of the ~~pest~~ Poles called ~~magnetic netral neutral plane~~. Armature Reaction.

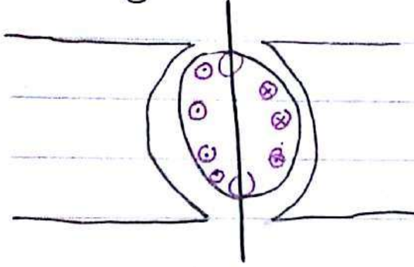
الموجود على إطار الآلة

Armeture Reaction caused two serious Problem: [1] ~~magnetic~~ netural shift plane

[1] magnatic neutral Plane: its a plane of the machine where the velocity is parallel to flux ~~density~~ Line, $\boxed{e_{ind} = 0}$ تتعامد الخطوط الأ شيئين

متساويين لما تحت الـ Magnetic Neutral تقسم العمل بالتساوي

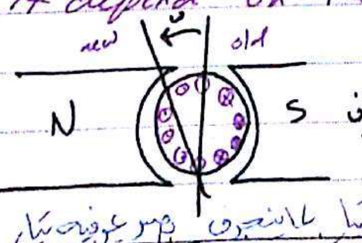
بالوضع الطبيعي ← الوسعة بتكون ثابتة



- Flux distrubuted uniformilly under the poles surface
- the voltage built out of the page under North Poles
- the Voltage built in the page under south poles
- Neutral plane is vertically.

- when a load is applied so the device is Generator.

the current will flow out of the page under the North Poles and in the page under the south Poles. this current will produce a magnetic filed that will effect the ~~act~~ original magnatic field which produce the voltage in the first place. (~~the~~ plane will be shifted in the direction of motion and it depend on the amount of current) for motor بعكس اتجاه الدوران



← ما يصير سنامباشر ناخذ الحصلة ومنها بنشئ الخط NML فمعرفش عن n.l الفراغ بين الـ Brushes والـ MNL ينتج منه sparks

و High losses. الـ commutator كله N.R ماعرفنا نها بالتحديد

[sparkes كل ما زاد التيار يزيد الانحراف يزيد الـ] Voltage ويقل الـ سرارة

No.

it cause sparkiling and areing in the brush $\xrightarrow[\text{to}]{\text{lead}}$ reduce the commutator life, increase mantinance, it can't be solved by replacing it (it may sparkle at no load)

high voltage will help to arc the ionized air
it can be lead to flashover in commutator → arc melt the commutator surface. show it

لو تفسير ان الهواء يكون موصل على الفراغ فبالتالي الاشتعال او حركة الايونات [illegible] الذي [illegible] ان الفولتية كبيرة

2. the second major problem caused by Armature Reaction called flux weaking.

الموتور شغال في operater نقطة قريبة الى Saturated point

يحدث زيادة بسيطة على الـ flux وبالتالي يحصل تغير كبير في الـ flux بشكل كبير [لأنه في منطقة ال saturation] small increase mmf + magnetic poles

huge decrease = mmf - pole mmf

Flux weakening
- → motors flux ↓ speed ↑
  - → machine disconnected
  - → motor distroy it self
- → generator Just reduce the voltage induced

$L\,di/dt$ Voltages:

happend in commutator segment called inductive kick.

high voltage → sparkiling

when the segment shorted the current reverse fast, a very high voltage

$\frac{di}{dt}$ → $L\frac{di}{dt} = V$ → انتقال التيار كبير → sparks → $L\frac{di}{dt}$ induced in the segment

معدل انتقال التيار يكون عالي [لأنه الموتور بيتحرك بسرعة فلحظة يكون قريب من الصفحات فلازم التيار يكون سريع

معدل انتقال التيار يكون سريع

داخل فراغ بسبب

No.

* Solution to Problems with commutation:

1. **Brush shifting:** if the neutral plane shifted why not to shift the brushes in order to stop sparkling.

<< بالتقريب بحول الـ فرشات بمبدو حد M.n.L بدل الـ neutral line عشان بيعطي نواخ >>

Problem with it:

١- نستطيع تحديد مقدار الانحراف لحالة ال rated value لكن الا حمال تغير على ال flux, ال voltage والتحميل على الـ Rate ...

ال flux على ال voltage، ال voltage مما تكرمية ...

٢- netural plane change with every change in load

٣- Shift direction reverse when it motor or generator

٤- it should would aggravated the flux-weakening

2- **commutating poles or interpoles:**

- الفكرة الرئيسية is to make the voltage in the wire zero → so there will be no sparkiling

* by connecting part called commutator poles winding in series with the windings of the motor, when the current flow it produce a flux then voltage opposes the voltage by the Armeture Reaction the net Result is zero

polarity:
- generator → poles → as same of the next upcoming main Pole
- motor → poles → polarities as same the previous main Pole

<< مابتحل مشاكل ال flux weakining >>

مابتحل ال flux وحل ... armeture reactio ... sparkling

flux weaking unsolved

$\Sigma V = 0$

No.

3- compensating windings: ملفات التعويض placing compenstating winding in series parallel to the rotor conductors. and in series with rotor winding [whenever the load change in the rotor the current in compenstating change too] **the sum of flux of compensating and rotor equal to the orginal pole flux** (magnaticmotive of compenstating equal and in opposite side of mmf of rotor force

disadvantages:

[1] too expensive

[2] must have poles [$L\frac{di}{dt}$ بالتبدل مشاكل]

$\Sigma \phi = 0$

7.7 Power Flow and losses in DC-Machines:

not all the power input appears as power out put efficiency $\eta = \frac{P_{out}}{P_{in}} \times 100\%$

$= \frac{P_{in} - losses}{P_{in}} \times 100\%$

The losses in DC-Machines:

1 electrical or copper losses → losses in the armature and field windings $P = I^2R$ / $I_f^2 R_f$ $I_A^2 R_A$

2 Brush losses $P = V_{BD} I_A$

3 core losses hysteresis eddy current losses

4 Mechanical losses
- friction in bearing
- windage [friction in moving part

5 stray load losses → one percent of the full load

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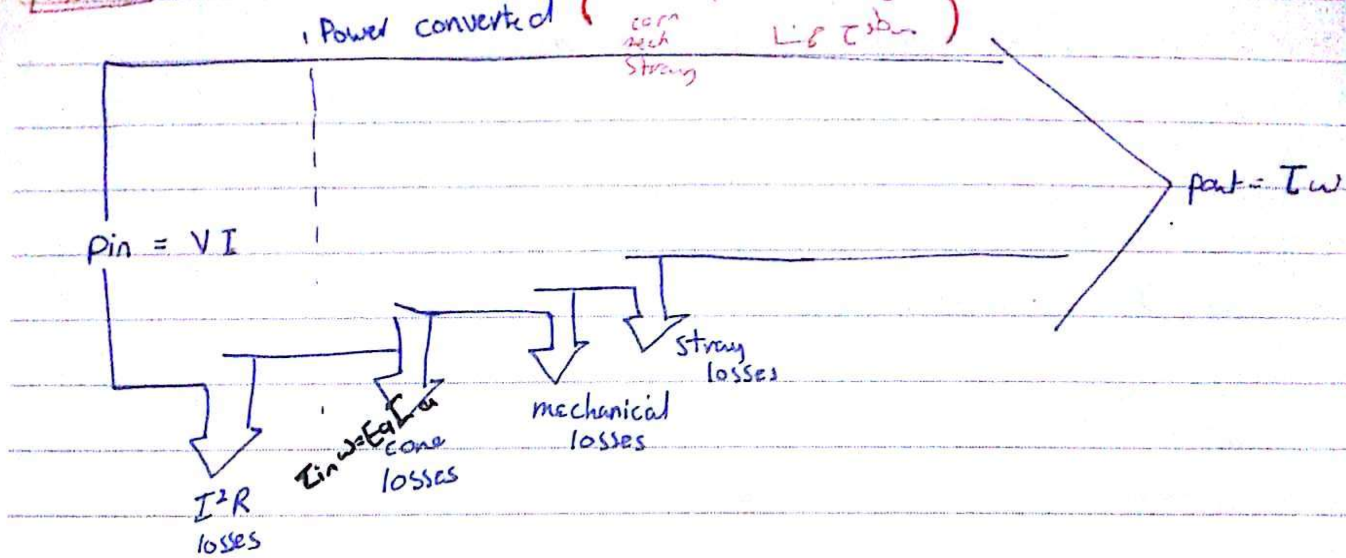
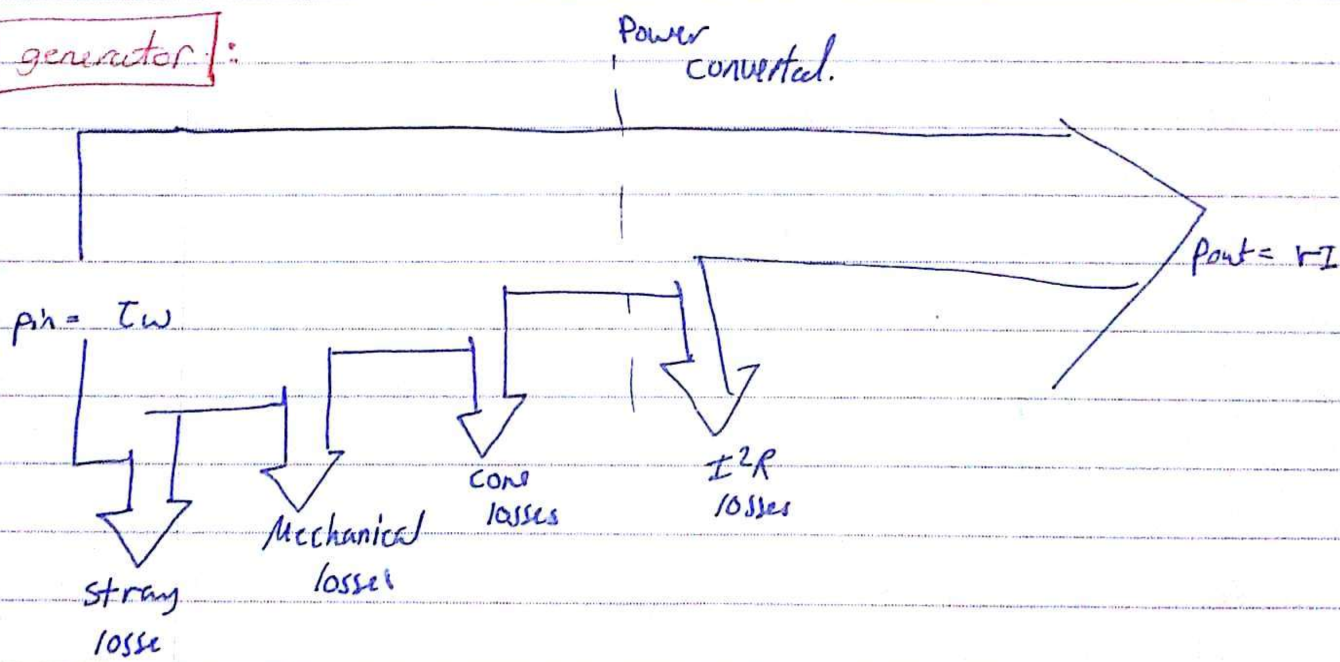
The Power flow diagram:

motor:



generator:



example :

$B = 0.4T$, $V_B = 48V$, $l = 0.5m$
$r = 0.25m$ $R = 0.4\,\Omega$ $\omega = 500 rad/s$.

1 Is this operate as machine at generator, Explane?

V_{em} $\bar{E} = \frac{2}{\pi} * B * \pi r l * \omega$

$\bar{E} = 2 * (0.4) * (0.25) * 0.5 \times 500 = 50$ ~~Em~~V

$V_{ind} > V_B$ generator.

2 what is the current ~~fo~~ flowing in to or out to the machine, power??

$i = \frac{V_{ind} - V_B}{R} = 5A$

$P = 5 \times 48 = 240$ by battery
$P = \tau\omega = 250$ by shaft

3 if the speed change to 550 rad / 450 rad Find current flow??

i ~~e_{ind}~~ $\frac{2(0.4)(0.25)(0.5)(550) - 48}{0.4} = 17.5$

$i = \frac{2(0.4)(0.25)(0.5)(450) - 48}{0.4} = -7.5$ motor

No

Chapter 8: DC MOTORS AND GENERATORS:

8.1 INTRODUCTION TO DC MOTORS:

DC motor are alften commpared by their speed Regulation (SR) =

$$SR = \frac{\omega_{no\,load} - \omega_{full\,load}}{\omega_{full\,load}} \times 100\,\%$$

$$SR = \frac{n_{no\,load} - n_{full\,load}}{n_{full\,load}} \times 100\,\%$$

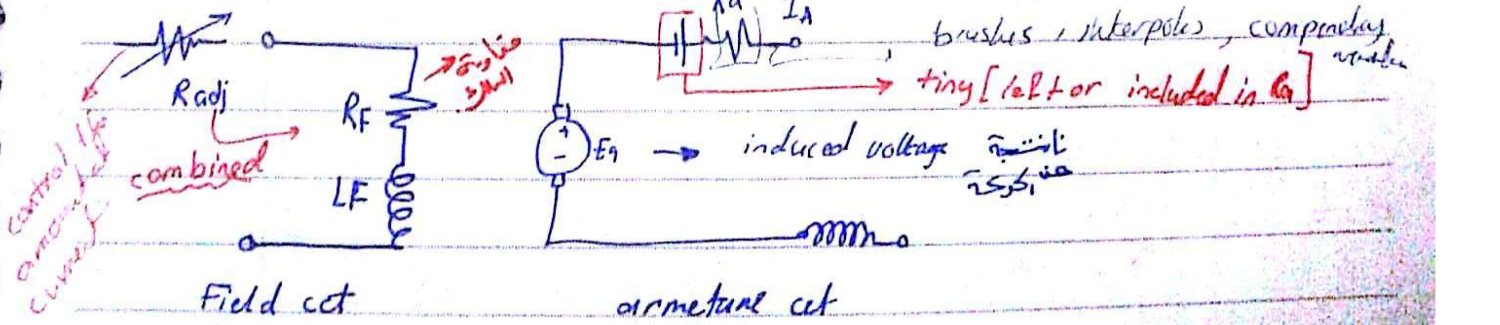
- (+) SR means that the motor speed drops with increasing loads
- (− SR) means that the motor speed increase with increasing loads

magnitude of (SR) = Slope of the tourqe - speed curve

* there are five major types of dc motors in general use:-

1. The separated excited dc motor
2. The shunt dc motor
3. The permanent-magnet dc motor
4. The series dc motor
5. The compounded dc motor

8.2 THE EQUIVALENT CIRCUIT OF A DC MOTOR:



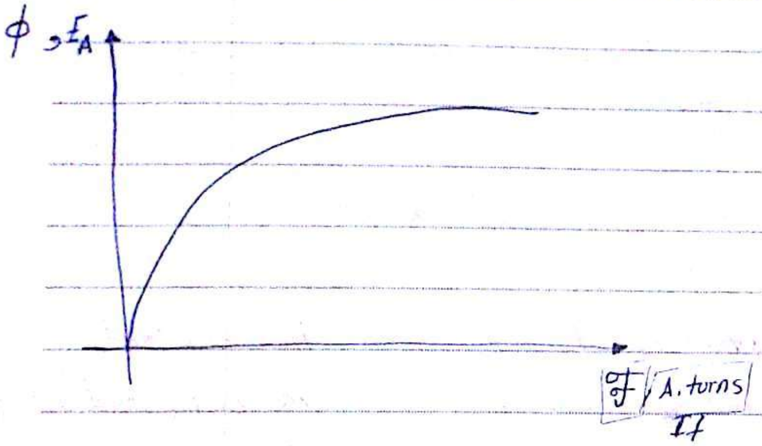
steady state → ملهوش ال Indactor → $\frac{di}{dt}$ = zero

No.

$E_A = K\phi\omega_m$ → generated voltage

$\tau_{in} = K\phi I_A$ → induced Torque

8.3 THE MAGNETIZATION ~~of~~ CURVE OF A DC MACHINE:



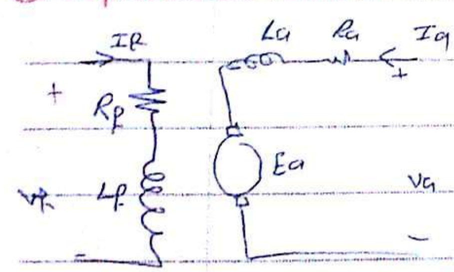
EA is directly proportional to ω_m and ϕ.
ϕ with Fmmf is shown because EA is proportional to ϕ so [ϕ with mmf] is shown.

• most machine operates in the region near the saturation point?
because huge increase in current will give us a little increase in Ea (voltage drop).

اشكال الـ dc motors:

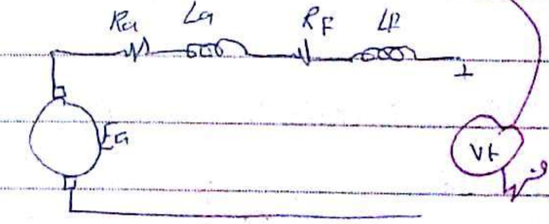
تم تغذيتهم بـ power supply

① Separated exited DC-Motor:

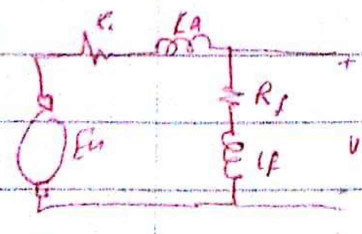


ϕ = Constant

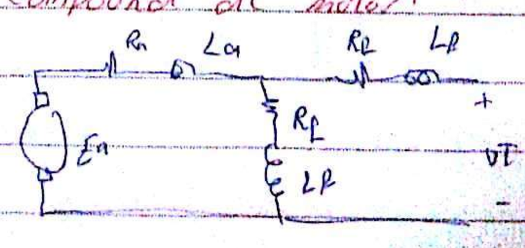
[2] series DC-Motor



[3] Shunt DC-motor



[4] compound dc motor



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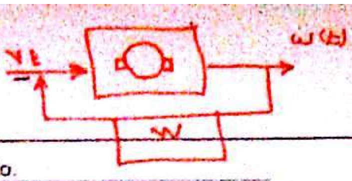
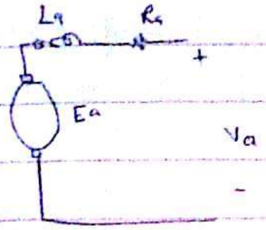


No.

[5] permenant magnatic dc motor



No field ckt → ماعنديش ملفات magnatic field

ϕ = constant.

هو عنا magnatic مغناطيس

8.4 SEPARATELY EXCITED AND SHUNT MOTORS: (ما بتغيرش ال voltage constant ما بكون في عندي احتمالات)

$V_T = E_A + R_a I_a + L\frac{di}{dt}$ → at steady state مشتقة الثابت = صفر

$V_T = E_A + R_a I_a$ حسب هذه المعادلة الموتور بقاوم التغير عادة حيث VB بالأغلب ثابتة

The Terminal Charactristic of a Shunt DC Motors:

it a plot of the machine's output quantities versus eachother.

* motor output quantity → Shaft tourqe
→ Speed

How a shunt motor respond to the load? when the load is increase the Toarqe will exceed the Tind, the machine slow down $\omega_n \downarrow$ $\boxed{E_a = k\phi\omega_n \downarrow}$ will decrease $I = \frac{V_B - E_a \downarrow}{R}$ increase, $\tau = k\phi i \uparrow$ increase

$\tau_{ind} = \tau_{lower}$ mechical speed of rotation ω_n

من اخطر الاشياء يروح ال فيلد عشان السرعة بتكون ∞

$~~E_a~~$ $V_T = E_a + R_a I_a$

$V_T = K\phi\omega_n + R_a I_a \xrightarrow{\text{Tourqe تولد}} \boxed{\tau_{ind} = k\phi i}$ $I = \frac{T_i}{k\phi}$

$V_T = k\phi\omega_n + R_a\frac{T_i}{k\phi}$

$y = cx + b$

$$\boxed{\frac{V_T}{k\phi} - R_a\frac{T_{ind}}{(k\phi)^2} = \omega_n}$$

T-ω charactrastic for sep. and shunt motor.

1

↳ constant [sep. excited أو permenant magnatic dc motor]

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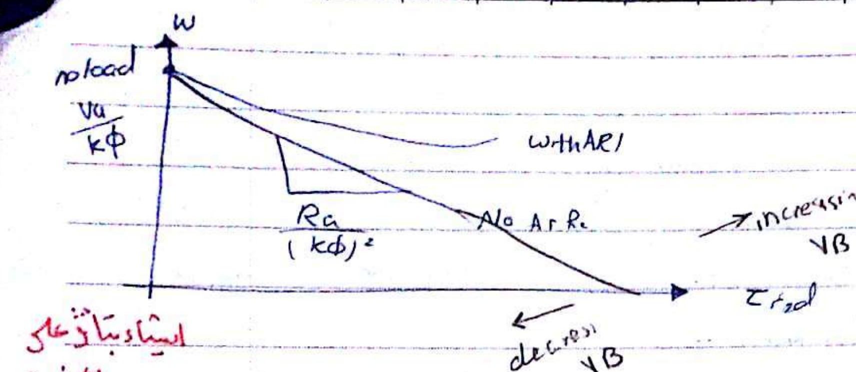


كل VB الو خط مستقيم

في طرفي يكون موتور
[generator ← ...]

اشياء بتأثر على المنحنى

① if ~~power~~ voltage supply is not constant → curve.

② Armature Reaction [with compensating winding بتحل المشكلة]

load ↑ $\phi \downarrow$

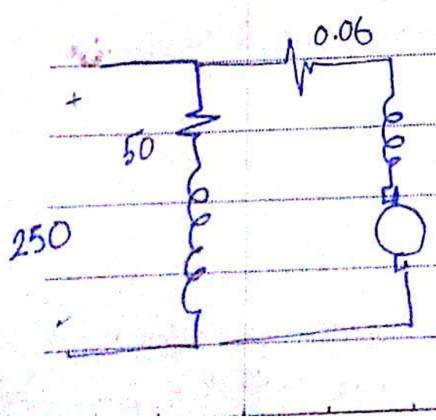
$i \uparrow \ \phi \uparrow \ \phi_{tot} \downarrow \ \omega \uparrow$

$\boxed{\text{Example}}$ A 50 hp, 250-V, 1200 r/min dc shunt motor with compensating winding has an armature resistance (including the brushes, compensating winding, interpoles) of 0.06 Ω. its field circuit has a total resistance $R_{adj} + R_F$ of 50 Ω, which produce a no load speed of 1200 r/min. There are ~~2000~~ 1200 turns per pole on the shunt field winding

a) Find the speed of this motor when its input current is ① 100 A ② 200 A ③ 300 A

b) plot the tourqe-speed characteristic for this motor.

compensating winding → ϕ constant



~~at no load speed $V_B = k\phi\omega$~~

~~$250 = k\phi(1200)$~~

~~$P = VI$~~ $I = 5A$

No.

power = 50hp

$V = 250V$

w [no load $\tau=0$] = 1200 r/min

compensating winding = ϕ [constant]

$R_A = 0.06\Omega$ $R_F = 50\Omega$ $N = 1200$

at $\tau = 0 \rightarrow I_a = 0$

$I_{tot} = I_F = \frac{250}{50} = 5A \rightarrow$ tourqe =0

a) $100 - 5 = 95$

$\tau = K\phi\, 95$

$V_B = E_a + \frac{\tau}{K\phi} R$

$250 = E_a + \frac{K\phi}{K\phi} 95(0.06)$ $E_a = 244.3V$

$244.3 = K\phi\, wn$
at no load $250 = K\phi\, 1200$] → tourqe =0

$\frac{244.3}{250} = \frac{wn}{1200}$ $n = 1173\, r/min$

b) $I_F = 200 - 5 = 195A$

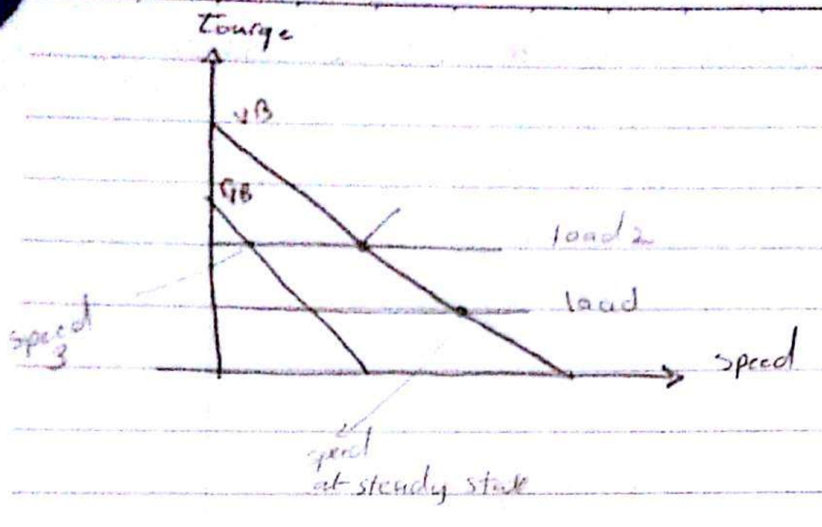
$V_B = E_a + I_a R_a$

$250 = E_a + 195(0.06)$ $E_a = 238.3V$

$238.3 = K\phi\, wn$

$250 = K\phi\, 1200$ $n = 1144\, r/min$

No.



> كل load الموسعة بحسب
> ما تزيد اللود تقل السرعة

وبعد اتقل العزم تقل السرعة

$\boxed{c}$

$I_A = 300 - 5 = 295 \uparrow \quad \omega_n \downarrow \quad \tau \uparrow$

$V_a = E_a + I_a R_a$

$250 = E_a + 295(0.06) \qquad E_a = 232.3$

$232.3 = k\phi\omega_n$

$250 = k\phi\, 1200 \qquad n_n = 1115 \text{ rad/s}$

$\boxed{d}$ $\quad \tau = k\phi i \qquad (E = k\phi\omega) \qquad k\phi = \frac{E}{\omega}$

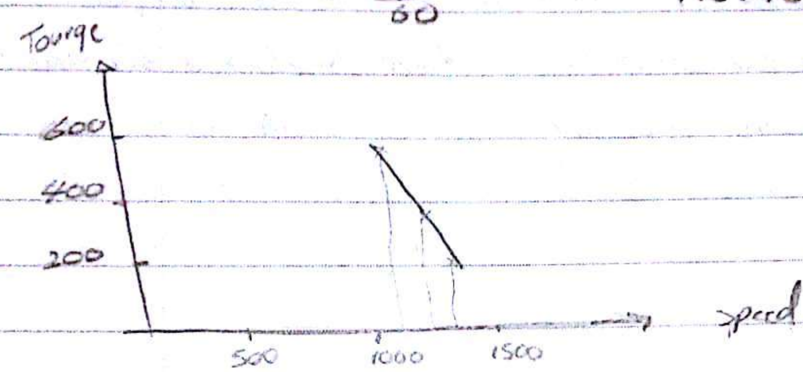
$\tau = \frac{E i}{\omega}$

$$\tau = \frac{95\,(284.3)}{1173 \frac{r}{min} \cdot \frac{1 min}{60 s} \cdot \frac{2\pi \text{ rad}}{r}} = \frac{95(284.3)}{122.83} = 190 \text{ N.m}$$

No.

$\tau = \frac{E_c}{\omega} = \frac{238.3\,(195)}{1144 \times \frac{2\pi}{60}} = \frac{238.3(195)}{119.79} = 388\,N.m$

$\tau = \frac{232.3\,(295)}{1115 \times \frac{2\pi}{60}} = \frac{232.3\,(295)}{116.76} = 587\,N.m$



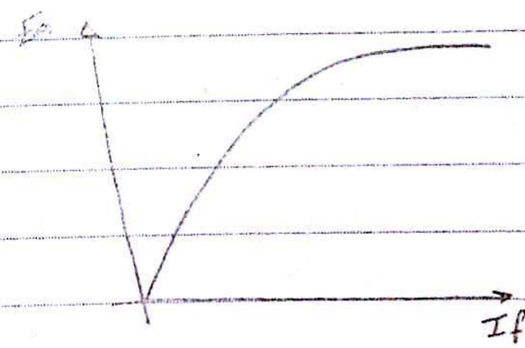
Non - linear Analysis of shunt DC-Motor

Flux ϕ and E_a (internal voltage) is non-linear with the mmf

الملاحظة
المستخدم
:شكل

$\mathcal{F}_{net} = N_F I_f - \mathcal{F}_{AR}$

$I_F^* = I_F - \frac{\mathcal{F}_{AR}}{N_F}$



Kirchhoff's law $\leftarrow \frac{E_A}{E_{A0}} = \frac{n_m}{n_0}$

initial references

No.

Example 50hp, 250V, 1200 r/min dc shunt motor without compensating winding has an armature resistance (including the brushes and interpoles) of 0.06 Ω. Its field circuit has a total resistance $R_F + R_{adj}$ of 50 Ω, which produce a no load speed of 1200 r/min, 1200 turns per pole on shunt field winding, and the armature reaction produce a demagnetizing mmf of 840 A.turns at a load current of 200A, curve is shown

a) find the speed of this motor when its input current is 200 A??

Solution:

at no torque $I_F = \frac{250}{50} = 5A$

$I_A = I_L - I_F$

$200 - 5 = 195A$

$V_B = E_a + 195(0.06)$

$250 = E_a + 195(0.06)$ $\boxed{E_a = 238.3\ V}$

$I_F^* = I_F - \frac{F_{AR}}{N}$

$5 - \frac{840}{1200} = 4.3A \rightarrow$ من المنحنى

$4.3 \rightarrow \boxed{233\ V = E_o}$

$\frac{E_a}{E_o} = \frac{n}{n_o}$

$\frac{238.3}{233} = \frac{n}{1200}$ $n = 1227\ r/min$

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No.

b) How dose it speed compare to that of the previous motor at a load current at 200A ??

$n_m = 1194$ r/min

$n_m = 1227$ r/min $\rightarrow R.A \uparrow \ \uparrow I$

c) Calculate and Plot the Torque speed for this reaction

MATLAP

*Control the speed of shunte dc-motor: (are the same for compounded DC-motor)

1. adjusting the field resistance.
2. " the terminal voltage applied to the armature.
3. Inserting a resistor in series with the armature cct.

1. Changing Field resistance:

$R_f \uparrow$ $I_f = \frac{V_T}{R_f \uparrow}$ decrease, ϕ decrease, $E_a = k\phi\downarrow\omega_m$ decrease,

$I_A = \frac{V_T - E_A\downarrow}{R_A}$ increase, $\tau = k\phi\downarrow I\uparrow$ ~~increase~~ ??

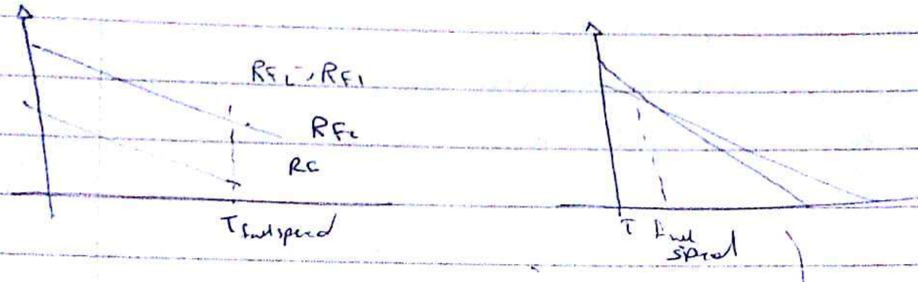
since $\tau_{ind} > T_{load} \rightarrow$ speeds up.

E_A increas current to fall, τ_{ind} fall too $T_{ind} = T_{load}$ at steady-state

No.

A warning about fitted field resistance speed control:

the effect of incresing the field resistance is shown



$R\uparrow$ $I_f\downarrow$ $\phi\downarrow$, speed no load increase $\uparrow$ $\frac{VB}{R}$ slope become steeper

at a very low speed

$R_f\uparrow$ in ideal $\omega\uparrow$ but acually speed decrese

[torque equation (لأنه الزيادة في Ea موجودة تحت مقابل زيادة في الحمل بالمعادلة)

[Rate speed (هاي الطريقة ممكن استخدامها بالمحركات اللي بدها تشتغل على ال rated)]

2. changing the armeture voltage. [without change the voltage of the field] motor must be sep.excited to use Voltage controller

1.) increase of V_a $\rightarrow$ $I = \frac{V_a - E_a}{R_a}$ increase

2.) current increase $\tau = k\phi I\uparrow$ increase $\rightarrow$ $\tau_{ind} > \tau_{load}$ speed up

3.) speed increase $E_a = k\phi\omega\uparrow$ increase

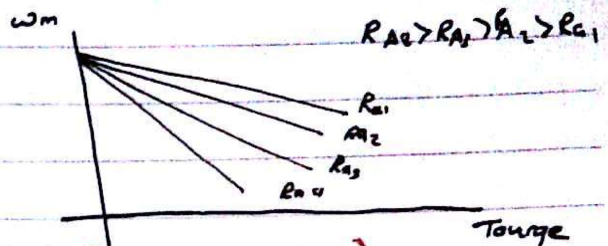
4). E_a increase $I = \frac{V_a - E_a\uparrow}{R_a}$ decrease

5). I decrease τ decrease $\tau_{ind} = \tau_{load}$

No.

3. Inserting a Resistor in series with the armature cct:

adding R in series will increase the slope, so the machine operate slowly



I ↓, T ↓, E ↓ [its very wastefull (loses are very large) for speed]. it's used in the expensive motor that we can't use a better way or motor operates all the time at full speed.

field Resistance control work with speed above the rate speed
armture voltage control work with speed less than the rate speed
[Combound these two controller in the motor will give a range 40 to 1 or more)

example: 100 Hp, 250 V, 1200 r/min shunt dc motor with an armeture resistance of $\boxed{0.03\,\Omega}$, $\boxed{R_F = 41.67\,\Omega}$ the motor has compensating winding AR ignored, mecanical and core losses ~~are~~ negligible, the motor assume to be driving a load with ~~line~~ load current of $\boxed{126\ A}$ and An initial speed of $\boxed{1103}$ r/m. [assume the amount of armeture current drawn by the motor remains constant]

① curve 8-9, what is the motor speed if the field resistance is 50Ω?

solution $I_A = I_{load} - I_F$

$$126 - \frac{120}{41.67} = 120\ A$$

$V_B = E_a + 120\,(0.03)$ $E_A = 296.39\ V$

$$\frac{E_a}{E_o} = \frac{n}{n_o} \rightarrow \frac{246.39}{} = \frac{n}{1103}$$

No.

$\cancel{\frac{E_a}{E_o} = \frac{n_a}{n_o}}$

$\cancel{I_L = 200}$ $R_f = 50$

$I_A = 126 - \frac{250}{50} = 121$

$250 = E_a + 121(0.03) = 246.37\ V$

$\frac{E}{E} = \frac{k\phi_1 n_1}{k\phi_2 n_2}$

$n_2 = \frac{\phi_1}{\phi_2} n_1$ $\frac{\phi_1}{\phi_2} = \frac{268}{250} = 1.076$

$1.076 \times 1103 = 1187\ r/min$

No.

Example: $\boxed{8\text{-}4}$ motor is sep. excited, the motor initially running with VA - 250v, IA = 120A and n = 1103r/min while supplying a constant tourge load, what will the speed of this motor be, if VA is reduced to 200v.?? RA = 0.03

$VA = RaIa + Ea$

$250 = 0.03(120) + Ea \qquad Ea = 246.4$

$200 = 0.03(120) + Ea \qquad Ea = 196.4$ [constant tourqe, I constant, ϕ constant]

$\frac{196.4}{246.4} = \frac{n}{1103} \qquad n = 874.17\ r/min$

The Effect of an Open Field circuit

If the field circuit is open ϕ decrease, Ea decrease, current A ↑ so the Tourge ↑ and the motor will speeds up

8.6 THE SERIES DC MOTOR: $Vt = Ea + Ia(Ra + R_s)$

Flux is proportional to armature current $\longrightarrow \phi = C\,Ia$

$\tau = k\phi i = kc(Ia)^2$

~~$Ea = k\phi\omega_n$~~

Tourge is proportional to the square of IA

series motor give more tourge

No.

~~The thermal thermal curve~~

The terminal characteristic of series DC motor:

$$VT = Ea + Ia(Ra + R_\ell)$$

$$VT = K\phi\omega_m + \sqrt{\frac{T_{in}}{K\phi c}}(Ra + R_\ell)$$

$\phi = cIa$ $\quad Ia = \frac{\phi}{c}$ $\quad \tau = k\phi I$

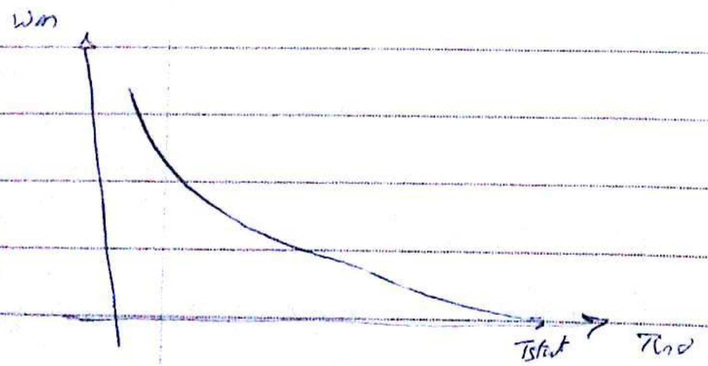
$$\tau = k\frac{\phi^2}{c}$$

$$\phi = \sqrt{\frac{cT}{k}}$$

$$VT = k\sqrt{\frac{cT}{k}}\,\omega_m + \sqrt{\frac{T_{in}}{kc}}(Ra + R_\ell)$$

$$\boxed{\omega_m = \frac{VT}{\sqrt{Kc}} \cdot \frac{1}{\sqrt{T_{ind}}} - \frac{Ra + Rs}{KC}}$$

when Torque goes to zero → speed ∞ [never completly unload series motor while running]



N.m ، التورك ء

No.

Example: 250 v series dc motor with compensating winding, and a total series resistance $R_a + R_s$ of 0.08Ω, 25 turns per Pole, magnetization curve shown 8-22

1- find the speed and induced ~~voltage~~ torque when $I_a = 50A$.

solution

$$V_B = E_a + I_a (R_{eq})$$

$$250 = E_a + 0.08 (I_a)$$

$$E_a = 246\ v$$

$$E_a = k\phi\omega_n$$

$$246 = K C I_A \omega n$$

$$\cancel{246 = KC \times 50 \omega n}$$

$$\cancel{80 = KC \times 50 \omega n}$$

من الكرف

$$F = NI = 25 \times 50 = 1250$$

$$E = 80$$

$$\omega n = 1200$$

$$\frac{80 = KCI\omega n}{246 = KCI\omega n}$$

$$\omega n = 3690$$

$$\tau = k\phi I = kC(I_A)^2$$

$$\tau = KC(50)^2$$

$$E = KCIA\omega n$$

$$\tau = \frac{E}{I\omega n} I^2$$

$$KC = \frac{E}{I\omega n}$$

$$\tau = \frac{E I}{\omega n} = \frac{80 \times 50}{1200 \frac{r}{min} \times \frac{2\pi}{60}} = \boxed{31.83 N.m}$$

No.

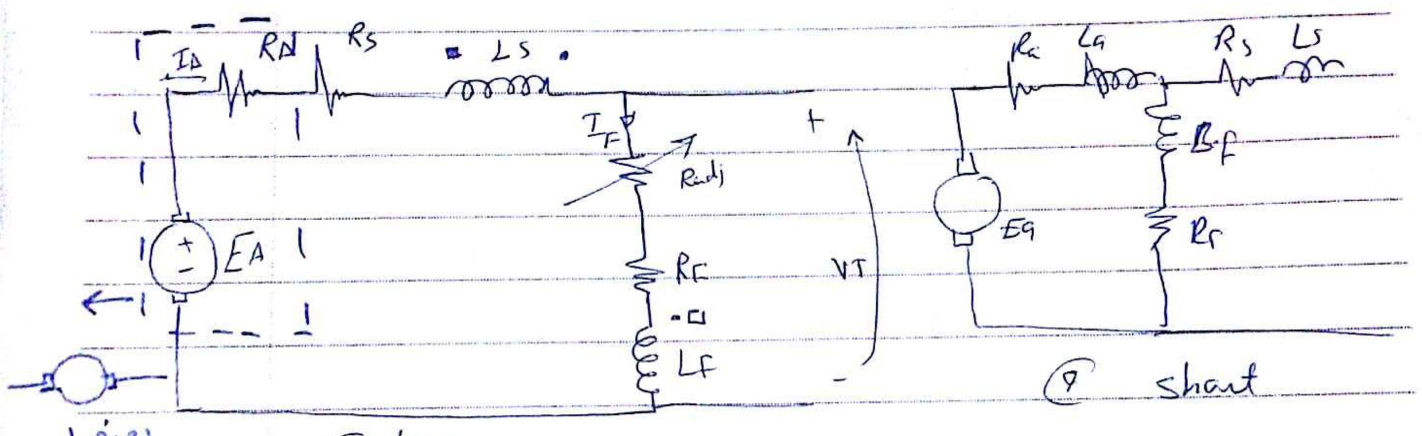
Speed control of series DC-motor

insertion a resistor in series its. wasthull

efficient way change voltage terminal:

$V\uparrow \left(\frac{V_T}{K C} \quad \frac{1}{K C_{ind}}\right) \uparrow$ voltage↑ speed↑

8.7 THE COMPOUNDED DC MOTOR: both shunt and series



③ long

④ short

① commulative compounding [the current into the dot in both coil (combain) (+) لما

② differential compounding عكس subtract - اذا دخل واحد داخل نقطة او داخل بوحدة، انتا بتحالها

$* \; V_T = E_a + I_A [R_a + R_s]$

$* \; I_A = I_L - I_F$

$* \; I_F = \frac{V_A}{R_F}$

$* \; \mathcal{F}_{net} = \mathcal{F}_F \pm \mathcal{F}_{SE} - \mathcal{F}_{AR}$

$* \; I_F^* = I_F \pm \frac{N_{SE}}{N_F} I_A - \frac{\mathcal{F}_{AR}}{N_F}$

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No.

The tourqe -speed characterstic of comulatively compounded DC-Motor

flux component $\rightarrow$ constant

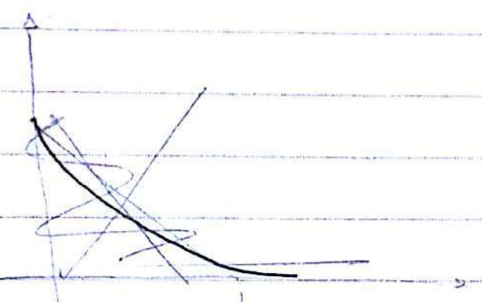
↳ proportional to its armeture current [I in strange]

* it has extra tourqe like series

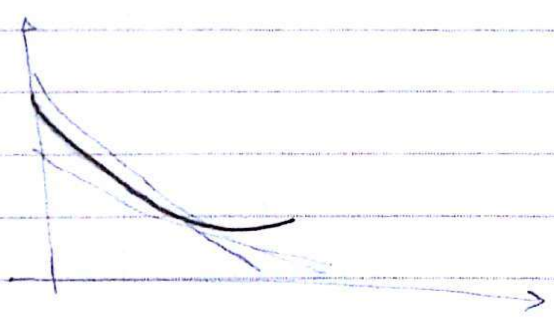
* it dose not overload ove speed at no load [like shunt motor]

at ~~#~~ light load it operate like shunt

otherwise it operate as series.



shunt



The tourqe -speed characteristic of differentially compounded DC-Motor.

$\text{shunt mmf} - \text{series mmf}$

load increase, I increase, ϕ decrease, speed increase, E_a increase, I_a decrease, speed decrease [unstable system]. ما بنستخدمه مش مستقر الا اذا طلبنا

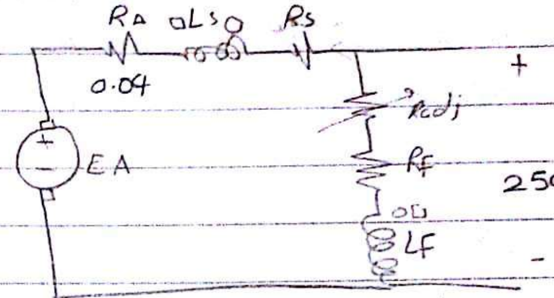
بـ short cct حيث بعمل لها shunt

~~123 6789~~

No.

example: A 100hp. 250V. commpounded DC-MOTOR with compensating winding internal resistance of 0.04 Ω   N = 1000 turns on shunt and 3 turns on series winding. [8-9] At no load field resistor has been adjusted to make the motor run at 1200 r/min [losses neglected]

a) what is shunt field current in this machine at no load?



at no load $I_a = 0$

250 → 5A

b) $I_A = 200A$, find speed? commulatively compounded

$250 = E_a + 200(0.04)$

$E_a = 242$

$I_F^* = 5 + \frac{3}{1000}(200) = 5.6A$

$\boxed{E = 262}$

$\frac{242}{262} = \frac{n}{1200}$ $n = 1108$ r/min

c) $I = 200A$, diff comp find speed??

$250 = E_a + 200(0.04)$ $E = 242$ $n = ??$

$I_F^* = 5 - \frac{3}{1000}(200) + 0 = 4.4$

$E = 236$ $n = 1200$

$n = 1230.5$

series , compounded $\longrightarrow$ non- linear

shunt, exi $\begin{cases} \to \text{non-linear} (\cancel{\text{AR}}\ \text{AR}) \\ \xrightarrow{\text{No.}} \text{linear} \end{cases}$

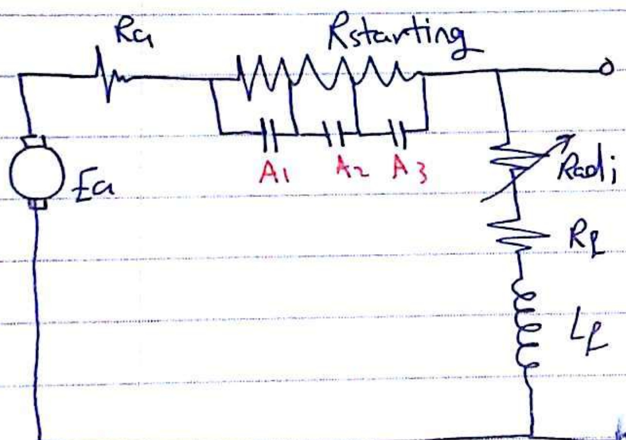
8.8 DC MOTORS STARTERS: مكونات اماشيا وحماية المتور:

to product the motor from short cct, High starting current, long term overloads help to control the operating speed of the motor.

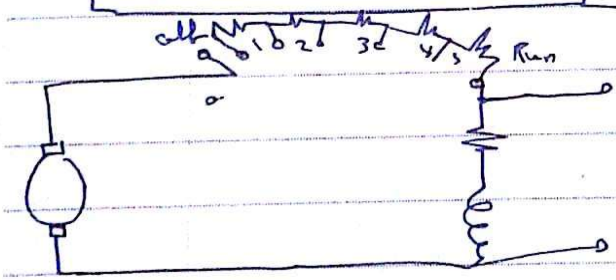
· Starting current $\xrightarrow[\text{happend due to}]{}$ $E_{a\,\text{at star}} = 0$

· Solution $\xrightarrow[\text{add}]{}$ resistor in series until the voltage induced build it self. with R_A.

not permantly (losses).



close A_1 A_2 A_3 (Rsta بنلغيها)



مشاكلها :

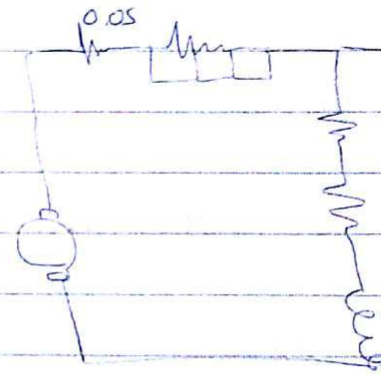
if it ~~run~~ cut slowly $\longrightarrow$ I too big

if it cut quickly $\longrightarrow$ burn out.

No.

example : 100hp. 250V , 350A shunt ~~dc~~. dc motor $R_A = 0.05\,\Omega$.
We wish to ~~ge~~ design a starter circuit for this motor which will limit ~~limit~~ the maximum starting current to twice its rated value and will switch off section when current falls to its rated value:

1) how many stage of starting resistance i need to limit the current to range specified



$$n = \frac{\log(R_A / R_{tot})}{\log(I_{min}/I_{max})}$$

$$R_{tot} = \frac{V_T}{I_{max}}$$

$$R_{tot} = \frac{250}{I_{max}}$$

$\cancel{I_{max} = \frac{250}{0.05}}$ $I_2 = 2I_1$ $\frac{I_2}{I_1} = 2$

$\frac{I_2}{350} = 2$ $I_2 = 700$

$$R_{tot} = \frac{250}{700} = 0.357$$

$n = 2.836 = 3$ resistor

No.

b) what value of each segment of resistor be ? At what voltage should each stage of the starting resistance be cutout??

$$I = \frac{V}{R_A + R_1 + R_2 + R_3}$$

$$700 = \frac{250}{R_A + R_1 + R_2 + R_3}$$

$$R_a + R_1 + R_2 + R_3 = 0.357$$

~~E_A~~ $V_A = E_A + RI$

$250 - 0.357(350) = E_a$

$E_a = 125$ → I_a has fallen to 350 A and its the time to cut the first starting (current must Jumb to 700)

$250 - (\ \ )(700) = 125$

$R = 0.1785\,\Omega$] total R in cct to fall to 350 A

E_a reaches

$E_a = 250 - 350(0.1785 = 187.5$

fall to 350 its time to cut the second one

$187.5 = 250 - 700(R)$

$R = 0.0892\,\Omega$

$E_a = 250 - 350(0.0892) = 218.75$

time to cut the third one

$R_3 = 0.0446\,\Omega$

$E_a = 250 - 700(0.0446) = 218$

$E_a = 234.39$

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No.

$$I_a = \frac{V_T - E_A}{R_a} = 625 = \frac{250 - 218.75}{0.05}$$

$$R_1 = R_{tot} - R_2 - R_3 - R_a$$

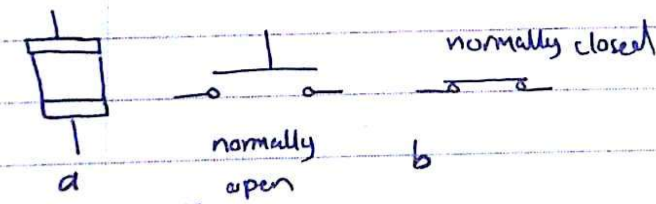
$$0.357 - 0.1786 - 0.0393 - 0.05 = 0.1071$$

$$R_2 = R_{tot} - R_3 - R_a = 0.0893$$

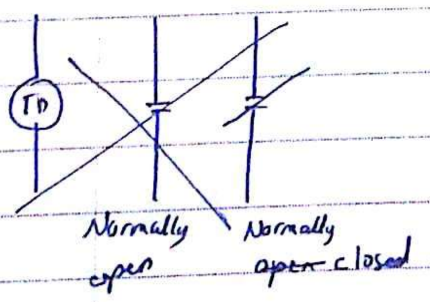
$$R_3 = R_{tot_3} - R_a = 0.0893 - 0.05 = 0.0393$$

DC Motor starting circuits:

fues $\longrightarrow$ to product the cct from short cct. (لما يصير في شورت سيركت بنحرقو بحميه السيركت من ما يصير اعطال).



spring type $\rightarrow$ normally open $\rightarrow$ closed when the button Pushed
spring type $\rightarrow$ normally closed $\rightarrow$ open " " " "



No.

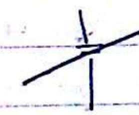
relay consist of Main coil and some contact

Main coil

nor. open

open when relay disconnected

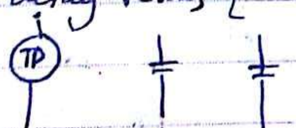
nor. closed



closed when relay disconnected

power → relay connect → switch st change.

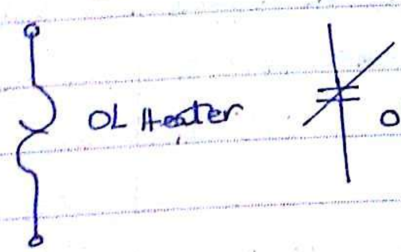
Time delay relay [مثل ال relay تماماً بس لما ينوصل بيجي في زمن قبل ما تتغير ال [contact



N.o N.c

overload [~~cont~~ consist → heater coil → some shut contacts

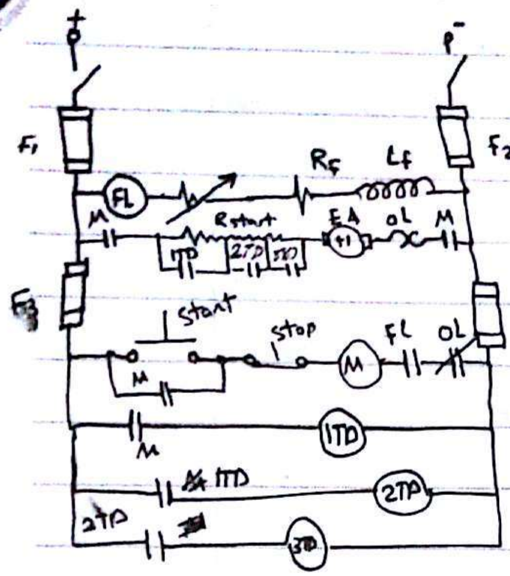
load حمل → ~~heater~~ current heat the coil heater up → shut contact

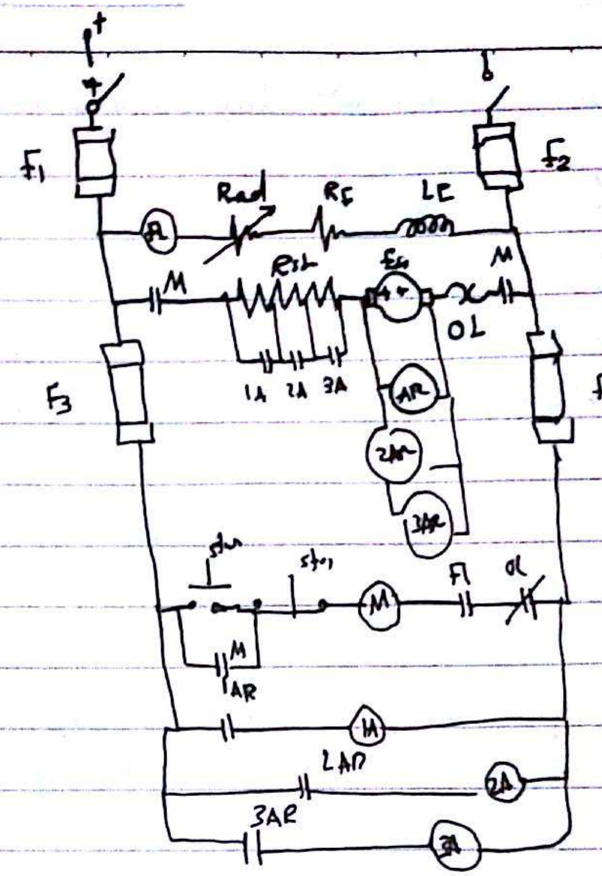


OL Heater

OL contact

No.





* serial of Time relay remove Resistance at the current time after the power applied supply.

كل ما يوصل 1TD بتسكر الـ contact تبعها
وبتشيل الـ جزء من starting resistance
لحد ما يوصل الموتور full load

its better than the previous

FL → field loss relay.

اذا التيار فقد لأي سبب من الأسباب هاي بتفصل
وبتفصل الموتور عن الـ power supply وبتوقف الحركة
اذا field current فقد

وفي over load بتسخن الـ Heater وبتفتح الـ OL
بتسكر الـ M relay وبتفصل الموتور عن الـ power supply

8.10 DC MOTOR EFFICIENCY CALCULATION:

copper losses I^2R →

عشان اوجد ال Resistance
بعمل ال Block لل rotor
نقسم ال $\frac{\text{voltage}}{\text{current}}$

* why the Resistance should be equal to full load? because it vary with tempreture. and full load will be near the operating tempreture.

the resulting resistance are not accurate:
1- The cooling that normally occurs when the motor is spinning will not be present
2- there is an ac - voltage in rotor ~~condition~~ conductors during normal operation, they suffer from some amount of skin effect, which further raises armature resistance.

$$\boxed{\text{Brush drop} = V_{BD} \cdot I_A}$$

turn freely - no load $\xrightarrow[\text{speed}]{\text{@ rated}}$ no output Power

no load → I_A small → copper losses neg.

No.

Example : A 50HP, 250V, 1200 r/min shunt dc motor, has arated armature current at IA 170A and a rated field current of 5A. when the rotor is blocked an armature voltage of 10.2V produce 170A of current flow, and field voltage of 250V produce a field current flow of 5A. voltage drop of Brush is 2V. at no load with terminal voltage equal to 240V. the armature current is 13.2A. the field current is 4.8A the motor speed is 1150 r/min

a) power is output at rated condition   2) efficiency.

$R_A = \frac{V}{A} = \frac{10.2}{170} = 0.06\ \Omega$

$R_f = \frac{V}{A}\ \frac{250}{5} = 50\ \Omega$

armature losses $= (170)^2 \times 0.06 = 1734$ w

field losses $= (5)^2 \times 50 = 1250$ w

Brush losses $= V_{Bd} \times I_A = 2 \times 170 = 340$ w

$P_{tot} = P_{core} + P_{mech} = (240)(13.2) = 3168$ w

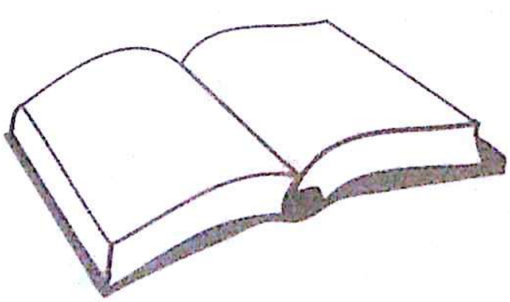
a) power output $= P_{in} - P_{loss}$

$(250)(175) - P_{arm} - P_{f} - P_{B} - P_{rot} - (0.01 \times 43750)$

$= 36820.5$

(2) $\eta = \frac{output}{in} = 84.2\%$

مَن لم يَحتَمِل ذُلَّ العِلمِ سَاعَة
بَقِيَ في ذُلِّ الجَهلِ أَبَدا



AC voltage apply on DC motor it will dosent work

Perminant magnatic circuit :

إيجابياتها ← صغيرة الحجم والسعر

سلبياتها ←

١- لا يمكن التحكم بها عن طريق flux

٢- اعطاؤها مادة ضعيفة ممكن تتكسر

٣- demagnitaization

ممكن تفقد مغناطيسيتها AR = magnatic from poles $e_g = 0$ مادة الفيرست

المادة ممكن تفقد مغناطيسيتها $\sigma = \infty$

درجة الحرارة تؤثر على المغناطيسية (unstable system)

FRANSFORMER: "chapter two"

2.1 why transformer are important to modern life:

→ high current causes ~~to~~ huge voltage drop in transmition line.

AC voltage

same frequency

→ transformer step up voltage and decrese the current to keep the power ~~eq~~ constant (in to equal out of device) & the the electrical Power can be generated over alonge distance at very low losses (losses will not allect high voltage) then it step down for final usage

التوضيح ← P preportional to I^2R

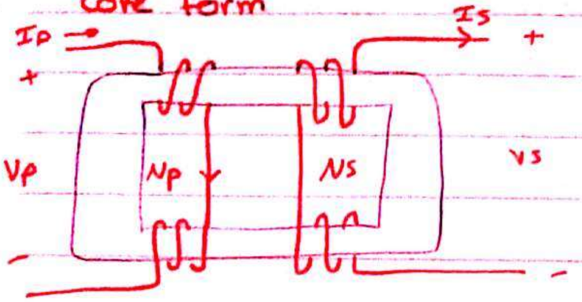
when the voltage increase and decrese the current the electric power will decrese twice.

---

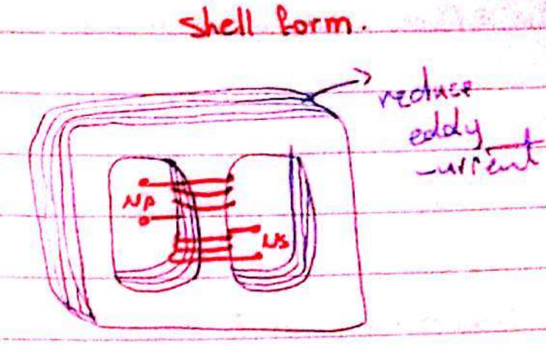
step up range (110kwatt - 1000k)
step down (12 545kw) → 120 V for safet usage

2.2 type and construction of transformers:

core form



shell form.



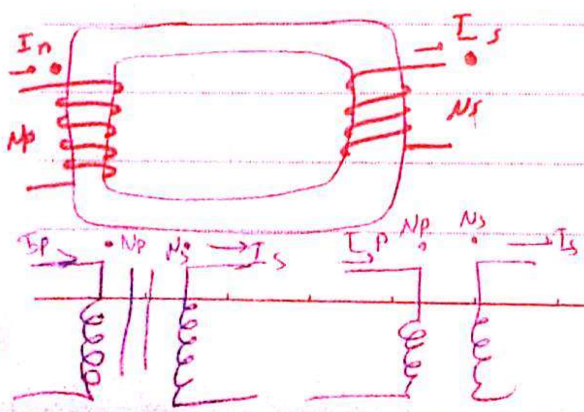
The primary and secondary winding is one on top of the other with low voltage :-

1. to simplific the problem of insulting the high voltage winding from the core
2. less leakage losses

name of transformer due to ~~its~~ their usage :-

1. duty (unit) transformer → step up voltage
2. substation transformer → step down voltage
3. distribution transformer → take the distribution and step it down to 220, 110.
4. potential transformer → sample high voltage to low sec voltage [small current]
5. power transformer → also produce sec voltage proportional to prim voltage
5. current transformer → provide sec current smaller than prim current

2.3 the ideal transformer



relationship between the voltage Vp and Vs

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} = a \text{ (turns ratio)}$$

$$\frac{i_p}{i_s} = \frac{1}{a}$$

لتحديد polarity (dot convention) :

1 - If the voltage is positive at the dotted end in primary side it will be positive at the dotted end of the secoundary side

2- If the current is flow in ~~to~~ to dotted side at primary, it will flow out of the dotted side at the secoundary side.

Power in Ideal transformer :-

- pout = pin

$V_{pri} I_{pri} \cos\Theta_p = V_{se} I_{se} \cos\Theta_s$

$\Theta_p = \Theta_s = \Phi$. $\longrightarrow V_p I_p = V_s I_s$

total power Real power ال power factor ( )

- Sin = Sout

$V_p I_p \sin\Theta_p = V_s I_s \sin\Theta_s \longrightarrow V_p I_p = V_s I_s$

a → > 1 step down
a → < 1 step up

Impedance Transformation through Transformer

$Z_L = \frac{V_p}{I_p}$ or $\frac{V_s}{I_p}$ → transformer change of voltage and current so

$Z'_L = a^2 Z_L$ [apperant Impedance in primary]

$= a^2 \frac{V_p}{I_p}$

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Analysis of circuit containing Ideal transformers:

replace the transformer with equivalent cct.

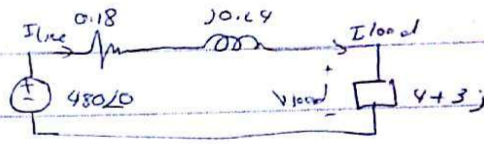
- reffering → Replacing one side of transformer with its equivalent at other side's voltage level

How to do equivalent cct ??

→ $\boxed{\frac{V_P}{V_S} = a}$ ① $\boxed{Z_L' = a^2 Z_L}$ ② polarity reverse direction

Example 2.1: A single phase power system consists of 480-V 60Hz generator supplying a load ~~Z~~load = 4+3i Ω through a transmission line of impedance ~~Zline = 0.18+j0.24~~

$Z_{line} = 0.18 + 0.24i$ Ω.



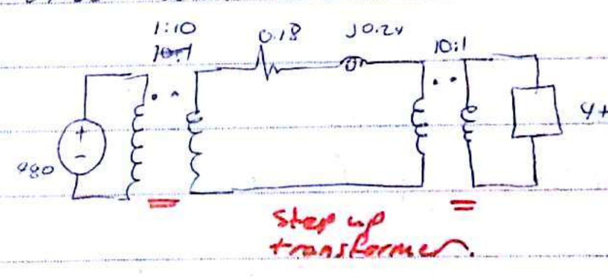
a) what will the voltage at the load be?

what transmission losses be??

solution $480 = (0.18 + 4 + 3j + 0.24i)\, I$ $\quad I = 90.8\angle -37.8$ A.

$V_{load} = I \times (4+3i) = 453.8 \angle 0.01$ V

transmission losses $= I^2 R = 1484.0352$ watt



b) what will the load voltage be, and transmission losses be?

$Z'_{load} = a^2 Z_L$

$\left(\frac{10}{1}\right)^2 (4+3i) = 400 + 300i$

$Z_{eq} = 400 + 0.18 + 300i + 0.24i = 500.3\angle 36.87$ Ω.

$Z'_{eq} = \frac{1}{a^2}(400.18 + i\,300.24) = 5.003\angle 36.87$ Ω

$I_G = \frac{480}{Z'_{eq}} = 95.94\angle -36.87$ A

$N_{P1} I_G = N_S I_{line}$

$I_{line} = \frac{1}{10}(95.94\angle -36.88\text{A}) = 9.594\angle -36.88$A

No

$N_{P} \overset{I_{line}}{\cancel{I_{load}}} = N_{S} \cancel{I_{line}} I_{load}$

$I_{load} = \frac{1}{10}$

$10\, I_{line} = I_{load}$

$= 95.98 \angle -36.88 A$

$V_{load} = I_{load} Z_{load}$

$95.94 \angle -36.88 \times 5 \angle 36.87 = 479.72 \angle -0.01 V$

losses $= \cancel{V} I_{line}^2 R = (01.594)^2 \times P(0.18) = 16.41$ watt

2-5 the equivalent Circuit of a Transformer:

* losses at transformer:

1. copper losses $I^2R \rightarrow$ Resistive heating [proportional to I^2]
2. eddy current losses $\rightarrow$ " " " to V^2
3. leakage losses $\longrightarrow \phi_{LS}, \phi_{LP}$ escaping from the core
4. hystresis losses

The exact equivalent circuit of a Real transformer

Copper losses $\xrightarrow[to]{equivalent} R_L, R_s$

leakage flux
- in primary produce voltage ϕ_{LP} $\quad e_{LP} = N_P \frac{d\phi_{LP}}{dt}$
- is secondary " " ϕ_{LS} $\quad e_{LS} = N_S \frac{d\phi_{LS}}{dt}$

$\phi_{PL} = (P N_P) i_P$
$\phi_{PL} = (P N_S) i_s$
directed proportionall.

$\hookrightarrow$ no. of turns inseco.

permenance of flux path $\frac{1}{R}$

مراجعة ميدترم

No.

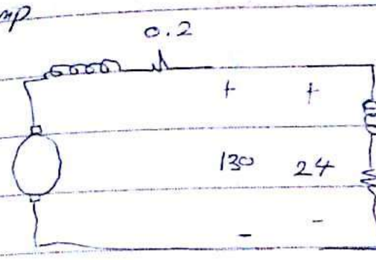
Example: Separtely excited DC- motor is rotated at 1000 rmp. under no load condition

I_f	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
V_T	0	30	60	85	102	115	124 / 142	130	134

$V_f = 24$, R_f is adjustable, $R_a = 0.2$, $V_a = 130$.

[1] field current at no load with 1000 rmp

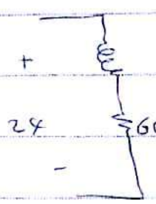
at $V_T = 130$ $I_f = 0.7A$



[2] motor drives a load at 1200 rmp. Calculate the armature voltage at 1200 rmp of the field Resistance $R_f = 60\Omega$.

$E_a = k\phi\ 1200$

$E_a = k\phi\ 1000$



$I_f = \frac{24}{60} = 0.4$

$\frac{E_a}{102} = 1.2$ $\boxed{E_a = 122.4}$ $E_a = 102$

[3] tourqe for above condition

$T = \frac{E_a i}{\omega} = \frac{122.4 \times I_L}{1200\left(\frac{2\pi}{60}\right)}$ $122.4 = 130 - I_L(0.2)$

$I_L = 38\ A$

$= 37\ N.m$

[4] Motor supplies Mechanical load of 4000 W at 1450 rmp the mechanical losses are 160 W calculate efficiency

$\frac{4000}{4000 + 160 + \text{field} + \text{Arm losses}}$

power converted $= 4000 + 160 = 4160$

$V_T I_a = E_a I_a + I_a^2 R$

$0.2 I^2 - 130 I_a + 4160$

$I_a = 33.75$

$E_a = 123.25$ $\frac{4160}{}$

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No.

$Ea = Ea$

$Ea = k\phi wn$

$\frac{123.25}{Ea} = \frac{1450}{1000}$ $\quad Ea = 85.006 \quad If = 0.3$

pinput = $(0.3)^2 \times \cancel{24}$

$\frac{24}{0.3} = \frac{0.3R}{0.3}$ $\quad R = 80$

$80(0.3)^2 + 0.2(33.79)^2 + 160 + 4000 = 4345$

$\frac{4000}{4345} \times 100\% = 91\%$

A series DC Motor has a combined armature and field resistance of $RA + Rs = 1.2\Omega$ $\quad VT = 48V$, tourqe develop 1500 Nm

[1] armature current and kc.

[2] tourqe when speed is 500 rmp

[3] output Power and efficiency when operating 500rmp (neglect mechanical losses)

(i) $I = \frac{48}{1.2} = 40\ A$

$\tau = kc(Ia)^2 \quad kc = 0.9375$

(ii) ~~48 = E~~

$\tau = 0.9375(I)^2 \approx 0.769 N.m \quad Ea = \cancel{0.9375}(500) = \cancel{468.75}$ 47.08

$k\phi$

~~468.75 = 48 - Ia(1.2)~~

$Ia = 0.9$

out put Power = $\tau w = 41.67$

power input

$\eta = \frac{E_A I_a}{V_T I_a} = 49.08$

Mechanical Power = $E_{induced} \cdot I_a$

No.

$\frac{500 \times 2\pi}{60} = \frac{50\pi}{3}$

$\tau = 0.9375 (I_a)^2$

$E_a = k\phi\omega_n \qquad \phi = cI_a$

$E_a = kcI_a \frac{50\pi}{3}$

$\boxed{E_a = 49.08\, I_a}$

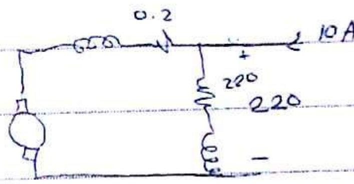
$48 = 49.08 I_a + I_a(1.2) \qquad \boxed{I_a = 0.955A}$

$\boxed{\tau = 0.854\, N.m}$

$\rho = \frac{E_a I_a}{V_T I_a} = \frac{49.08(0.955)}{48} = 97.6\%$

A 220 V shunt motor has armeture and field resistance of 0.2 Ω and 220 respectivel. The motor is driving a constant load Tourge and running at $\boxed{1000\ rpm}$ drawing 10A current from the supply. Calculate the new speed and armture current if an external armeture Resistance of 5 Ω is inserted. Neglect armatureaction.

solution



$I_f = \frac{220}{220} = 1\ A$

$I_a = 9A$

$220 = 5.2(9) + E_a \qquad E_a = 173.2 \rightarrow \omega = ??$

$220 = 0.2(9) + E_a \qquad E_a = 218.2 \qquad 1000$

$n = 793.76\ rPm$

220 V shunt motor has $R_A = 0.2$ $R_f = 220$. The motor is driving load Tourge $\propto n^2$ and running at 1000 rpm drawing 10A from supply. calculate tourge. when 5 Ω is inserted in armture cct.

$I_a = 10 - \frac{220}{220} = 9A$

~~220 = 0.2(9) + Ea Ea =~~

$\rightarrow$

No.

$e_{Lp}(t) = L_p \frac{di_p}{dt}$ $\quad$ $e_{Ls}(t) = L_s \frac{di_s}{dt}$

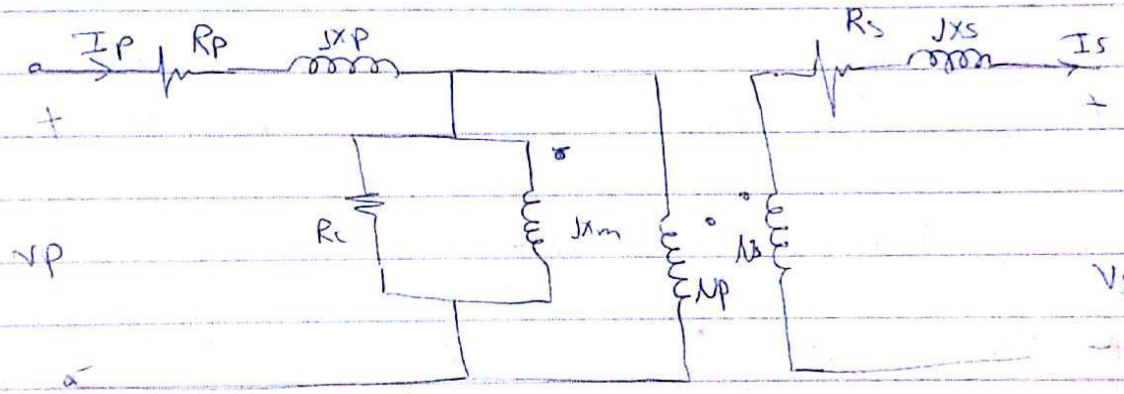
$L_p = N_p^2 \mathcal{P}$ → leakage inductance in primary.

I_m (magnetization current) proportional to $\underline{V}$ (voltage in the core) and lagging it by 90

so we can represent it by X_m connected across primary voltage.

I_{h+e} [hystresis and eddy current] proportional to V and in phase with it

so it modeled as R_c connected across the pri voltage



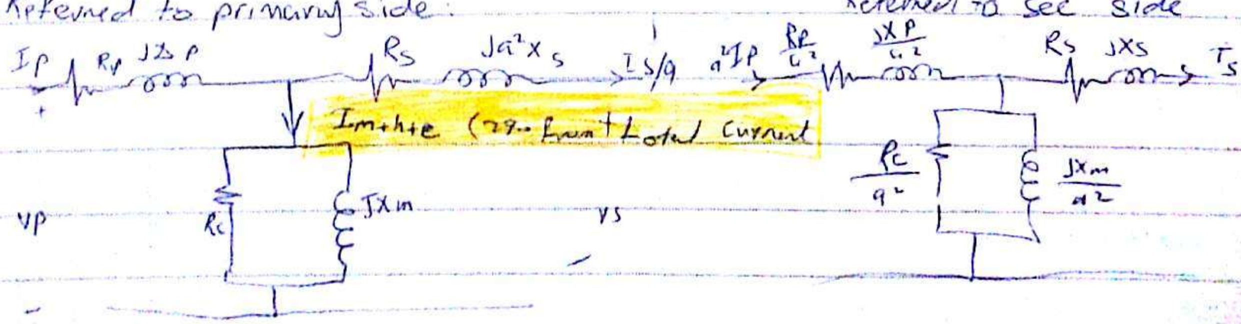
$X_p = \omega L_p$ reactance due to primary

$X_s = \omega L_s$ Reactance due to secondary

$\left(\frac{V_p}{V_s} = a \right)$ $\qquad$ ϕ الليكج هاي بيستخدمها للحل

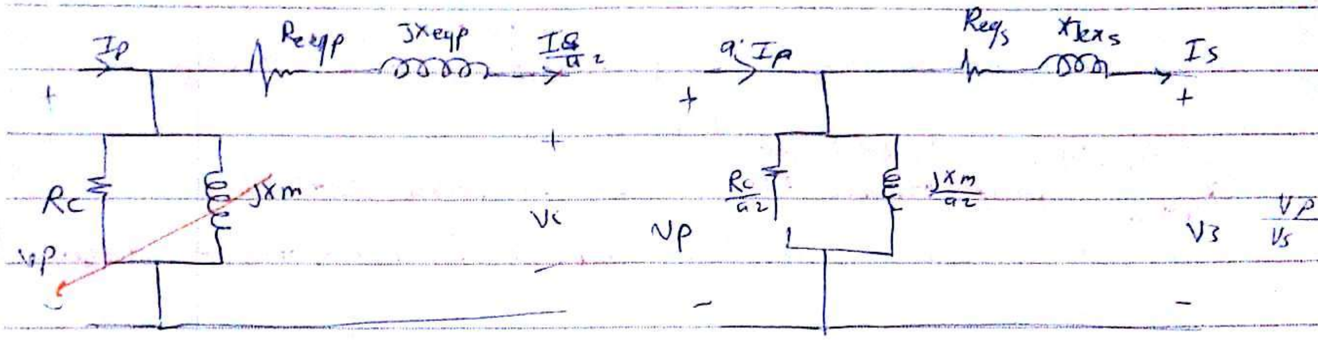
Redraw

Referred to primary side: $\qquad$ Referred to sec side



Approximate Equivalent cct of a Transformer:

because excitation current (I_{m} ...) is 2÷3% of total current cct can be simplified.



$$R_{eqp} = a^2 R_s + R_p$$
$$jX_{eqp} = a^2 jX_s + jX_p$$

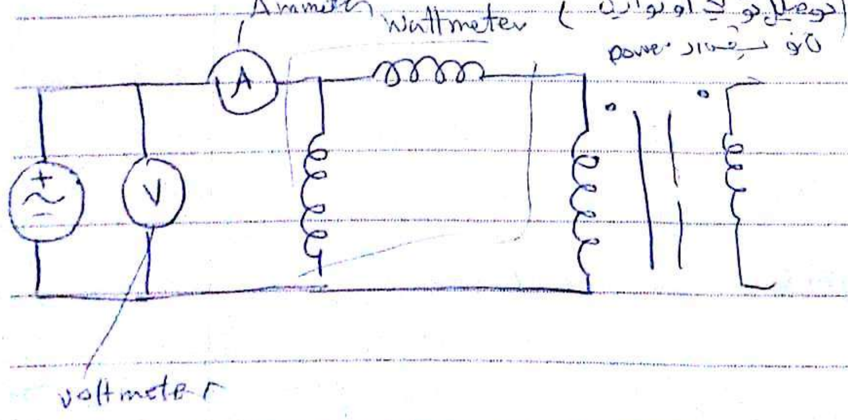
$$R_{eqs} = \frac{R_p}{a^2} + R_s$$
$$jX_{eqs} = \frac{jX_p}{a^2} + jX_s$$

no excited current

$$\frac{I_p}{I_s} = \frac{1}{a}$$

no excited current

Determine the value of Components in transformer models:



I zero ↗ V maximum No.

[1] open cct test [low voltage side] يتم توصيل الـ ... بالـ
Rated low voltage

excitation [...] full line voltage
Branch
[Rc xm

impedance mag and angle for excitation power factor

$$G_C = \frac{1}{R_C} \qquad B_M = \frac{1}{X_m}$$

V rated = V open cct.

$$G_C = \frac{I_{o.c}}{V_{.oc}} \times \cos\phi \qquad B_M = \frac{I_{o.p}}{V_{o.p}} \times \sin\phi$$

(2) $\phi = \cos^{-1} \frac{P_{o.p}}{V_{o.c}\, I_{o.c}}$

(1) $I_{o.c}$
$P_{o.c}$
$V_{o.c}$

Reffered to low voltage side [...]
لو بدي على primary بضرب بـ a^2

[2] short cct test [to High voltage side] ... rated value
voltage = 0 · I maximum.

low voltage of transformer is shorted

series elements [... losses ... excited Bransh ...]

$$|Z_{sc}| = \frac{V_{sc}}{I_{sc}} \cos \angle\phi$$

I rated = I short cct

$$\phi = \cos^{-1} \frac{P_{sc}}{V_{sc}\, I_{sc}} \qquad R_{eq} = Z_{sc}\cos\phi$$
$$X_{m\,eq} = Z_{sc}\sin\phi$$

Refered to high voltage side

No.

Example 2-2 : The equivalent cct impedances of a 20 kVA, 8000/240 V, 60 Hz transformer are to be determined. The open circuit test was performed on the secondary side of transformer, and short cct test were performed on the primary side

Open circuit test

V_{oc} 240 V

I_{op} 7.133 A

V_{oc} = 400 W

Short circuit test

V_{SC} = 489 V

I_{SC} = 2.5 A

$P_{sh.c}$ = 240 W

Find the impedances of the approximate equivalent circuit reffered to the primary side, and sketch the cct.

Solution:

Open cct [low voltage source]

$$\phi = \cos^{-1}\frac{400}{240 \cdot 7.133} = 76.48^\circ$$

$$Y_E = \frac{7.133}{240} = 0.0297 \angle{-76.5} \rightarrow 6.933\times10^{-3} - 0.02887i$$

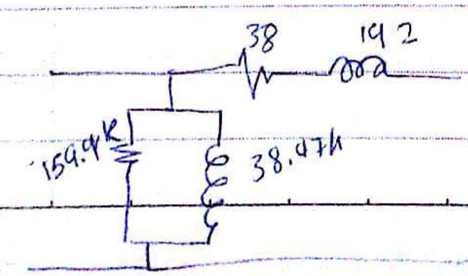
$$R_c = \cancel{\frac{1}{0.0297}} \qquad R_c = \frac{1}{6.933\times10^{-3}} = 144.23\Omega \rightarrow (33.33)^2\, 144.23 = 159.9k$$

$$X_m = \frac{1}{0.02887} = 34.63\Omega \qquad (33.33)^2 \times 34.63 = 38.47k$$

pf = shorted

$$pf = \frac{240}{489 \cdot 2.5} \qquad \phi = 78.67^\circ$$

$$Z_{eq} = \frac{489}{2.5} \angle \cos^{-1}\phi = \underbrace{38.42}_{R_{SE}} + \underbrace{191.78i}_{X_{SE}}$$



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No.

2.7 transformer voltage regulation and efficiency:

output voltage dependent on the load of impedances even if input voltage is constant

Voltage regulation% → $\frac{V_{s\,no\,load} - V_{s\,full\,load}}{V_{s\,full\,load}} \times 100\%$ $V_S = \frac{V_P}{a}$

$\frac{V_P/a - V_{s\,full}}{V_{s\,full}} \times 100\%$

high VR and Impedance reduce the fault current in cct.

how to determine Voltage regulation

it depended on the impedances and the angel of current flow in the transformer

by drawing phasor diagram V_s = at angle 0° and all element compare with it

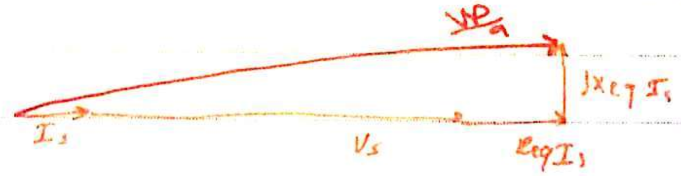
$\frac{V_P}{a} = V_S + R_{eq} I_S + jX_{eq} I_S$

with lagging PF

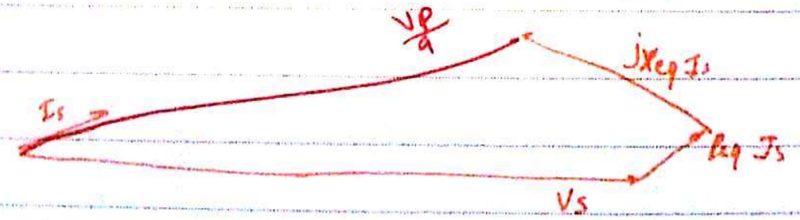
greater than zero.

$\frac{V_P}{a} > V_S$

unity power factor



leading PF



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No.

Transformer Efficiency - transformer also compared by their efficiency

$$\eta = \frac{P_o}{P_i} \times 100$$ — copper losses, eddy current loss, hysteresis losses

$$\eta = \frac{V_S I_S \cos\phi}{p_{cu} + P_{core} + V_S I_S \cos\phi} \times 100\%$$

Examples: A 15 kVA, 2300/230 V transformer is to be tested to determine the excitation branch component, its series impedances, and its voltage regulation

Open circuit test (low voltage side)

$V_{oc} = 230V$

$I_{oc} = 2.1\ A$

$V_{oc} = 50W$

Short circuit test (high voltage side)

V_{sc} 47 V

$I_{s.c}$ 6 A

$V_{s.c}$ 160W

a) Find the equivalent cct referred to high voltage side

Short cct

$\phi = \cos^{-1} \frac{160}{47 \times 6} = 55.43$

$Z_{eq} = \frac{47}{6} = 4.44 + 6.45j$

R_{sc} X_{sc}

open cct

$\phi = \frac{50}{230 \times 2.1} = 84.05$

$Y_{eq} = 9.45 \times 10^{-4} + 9.08 \times 10^{-3} i$

$R_c = 105.82 + 110.13i$

X_m Y_m

R_c electroprime $\left(\frac{2300}{230}\right)^2 10582$

$Y_m = 11013$

No.

b) Find the equivalent cct due to low voltage side

$R_{SE} = \frac{4.45}{100} = 0.0445$

$X_{SE} \frac{6.45}{100} = 0.0645$

c) calculate the full load voltage regulation at 0.8 lagging PF, 1 pF and 0.8 leading PF using the exact equation for V_P

$VR = \frac{V_{s\,no\,load} - V_{s\,full\,load}}{V_{s\,full\,load}} \times 100\%$

$I_S = \frac{P_s}{V_s} = \frac{15000}{230} = 65.2$

$\frac{V_P}{a} = V_s + R_{eq} I_s + X_{eq} I_s$

$230 + 0.0445\ 65.2\angle 36.86 + j0.0645 \angle{-36.86}$ $\quad -0.8 = 0-\emptyset$

$\frac{V_P}{a} = 229.85 \quad 234.85 \angle 0.40\,V \qquad VR = 2.1\%$

$\frac{V_P}{a} = 230 + 0.0445(65.2\angle 0) + j0.0645(65.2) \qquad 1 = 0-\emptyset$

$= 232.93\angle 1.03$

$VR = \frac{232.93 - 230}{230} = 1.3\%$

$\frac{V_P}{a} = 230 + 0.0445(65.2\angle 36.86) + j0.0645(65.2\angle 36.86)$

$\frac{V_P}{a} = 229.85\angle 1.2$

$VR = \frac{229.85 - 230}{230} = -0.065\%$

d) efficiency of the transformer at full load with PF = 0.8 lagging

$\eta = \frac{V_s I_s \cos\emptyset}{V_s I_s + P_{cu} + P_{core}}$

No.

$P_{cu} = (I_s)^2 R_{eq}$

$0.0445 \times \left(\frac{15000}{230}\right)^2 = 189W$

$P_{core} = \frac{(V_P/a)^2}{R_C} = \frac{(239.85)^2}{1050} = 52.52$

$V_P = 230 + 0.0445\left(\frac{15000}{230}\right)\angle\cos^{-1}0.8 + 0.0645\left(\frac{15000}{230}\right)\angle\cos^{-1}0.8$

$V_s I_s \cos \quad 230 \times 65.2 \angle -36.86 = 11998.35$

$\frac{11998.35}{11998.35 + 52.52 + 189} = 98\%$

2.8 TRANSFORMER TAPS AND VOLTAGE REGULATION

distribution transformer [±2.5% - ±5%]

example 500 kVA, 13200 / 480 V distribution transformer has four 2.5 percent taps on its primary winding. what is voltage ratio for the transformer per tap setting

5% 13860 / 480 V.

2.5 13530 / 480 V.

norm. 13200 / 480 V.

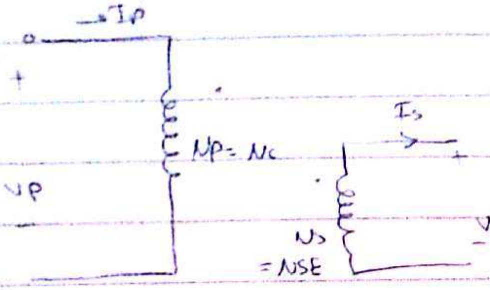
-2.5 12870 / 480 V.

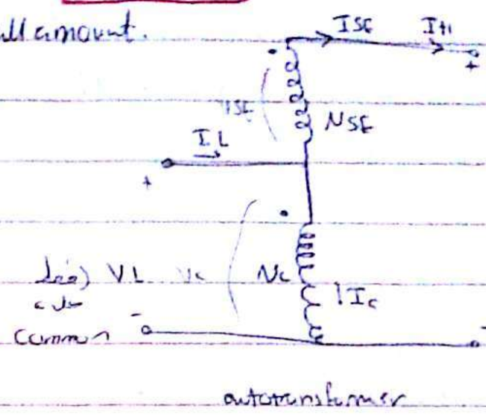
-5% 12540 / 480 V.

No.

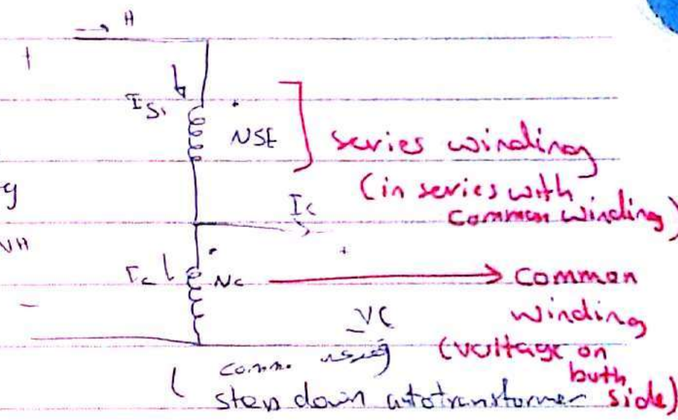
2.9 THE AUTOTRANSFORMER: $\boxed{\text{self-study}}$

use to change voltage level by a small amount.





connected in the conventional manner



total Voltage output = V on first winding + V on sec winding
input

primary side where the power into it

depending on it step up or down

$I_L = I_{SE} + I_C$ $\qquad$ $V_H = V_C + V_{SE}$

$I_H = I_{SE}$ $\qquad$ $V_L = V_C$

$I_C N_C = I_{SE} N_{SE}$

$\frac{V_C}{V_{ES}} = \frac{N_C}{N_{ES}}$

$$\boxed{\frac{V_L}{V_H} = \frac{N_C}{N_{ES} + N_C}} \qquad \frac{I_L}{I_H} = \frac{N_{ES} + N_C}{N_C}$$

Apperant Power in transformer: [Not all power travelling in the winding]

$$\cancel{P_1} \quad \frac{S_{IO}}{S_W} = \frac{N_{ES} + N_C}{N_{ES}}$$

power enter prim leave sec

S_W — power travelling in winding

Example: 100 kA, 120/12 -V transformer is to be connected so as to form a step up autotransformer $V_P = 120$ is applied to transformer.

1) secondary voltage

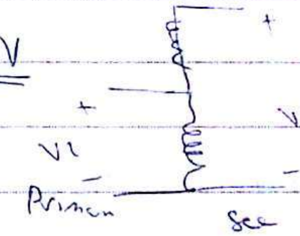
2) maximum volt amper rating in this mode of operation

3) rating advantage of autotransformer connection over the transformer rating conventional of 120/12-V operation.

solution :

$$\frac{\cancel{V_L}}{V_H} = \frac{N_C}{N_{ES}+N_C} \qquad V_H = \frac{12+120}{12}\ \cancel{V_L}\,120$$

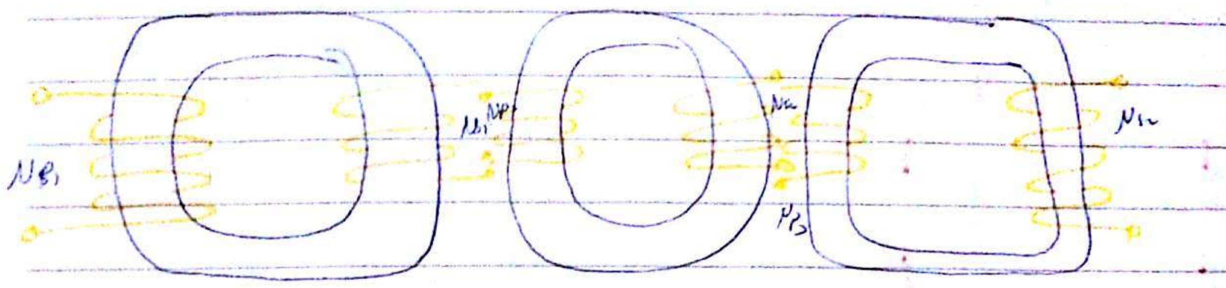
$$\underline{V_H = 132\ V}$$



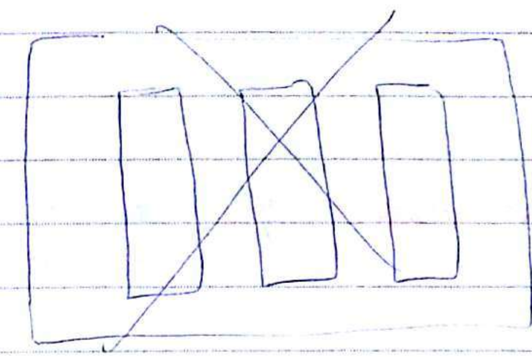
$$I = \frac{P_{max}}{V} = \frac{100}{12} = 8.33$$

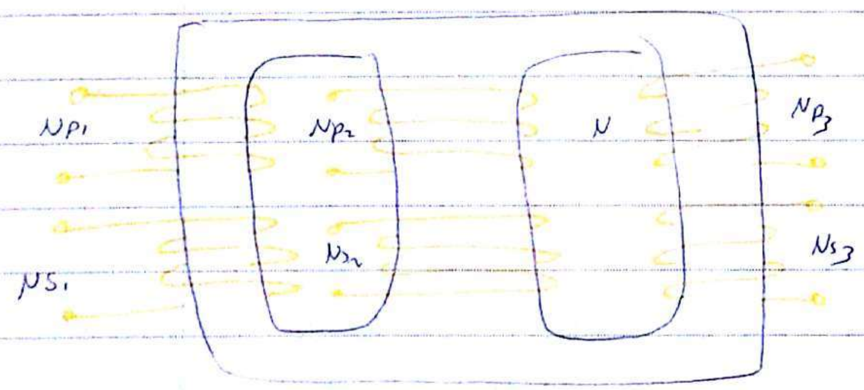
No.

THREE PHASE TRANSFORMER:



each unit can be replaced if sth trouble happened





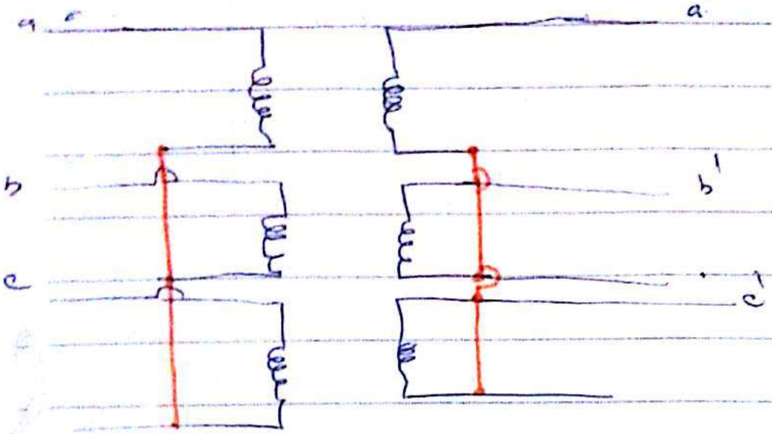
Smaller
lighter
Cheaper
more efficiently

single three leg

Connection [[illegible]]

- YY
- YΔ
- ΔY
- ΔΔ

WYE - WYE connection:-



$V_P = \frac{1}{\sqrt{3}} V_{SE}$

So

$\frac{V_P}{V_S} = \frac{V_P}{\sqrt{3} V_P}$

$V_{\phi P} = \frac{1}{\sqrt{3}} V_{LP}$

$V_{L S} = \sqrt{3} V_{\phi S}$

Vp 120 apart in any other voltage

$\boxed{\frac{V_P}{V_S} = \frac{\sqrt{3}\ V_{\phi P}}{\sqrt{3}\ V_{\phi S}} = a}$

(1) عيوب

(1 if load unbalanced voltage phase can become unbalanced

(2 third harmonic can be large (noise

(2) الحلول

(1 grounded the neutral line (provide a return path for any current imbalanced the load)

(2 add a third winding connection Δ

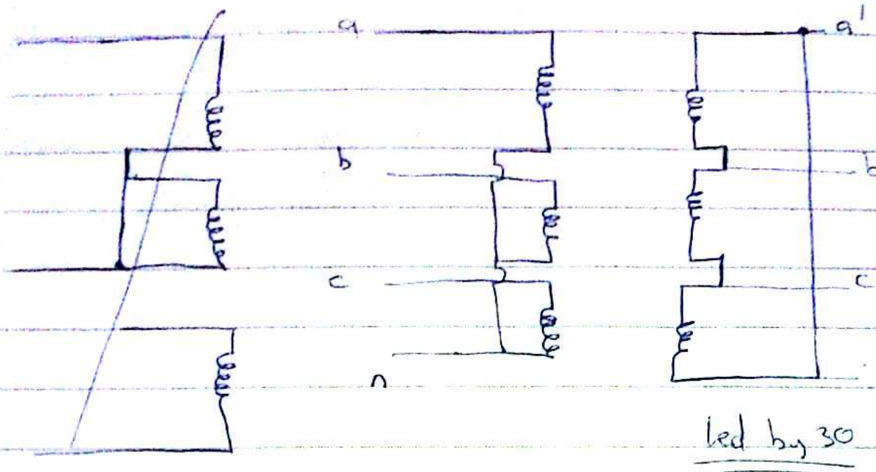
WYE DELTA CONNECTIONS

$V_{LP} = \sqrt{3} V_{\phi P}$

$V_{LS} = V_{\phi S}$

$\frac{V_{LP}}{V_{LS}} = \sqrt{3} a$

No.



led by 30

- its has no harmonic problem becaus. of Δ connection
- secondary connection shifted 30° relative to Primary , can cause problem in parallel connection

DELTA WYE CONNECTION

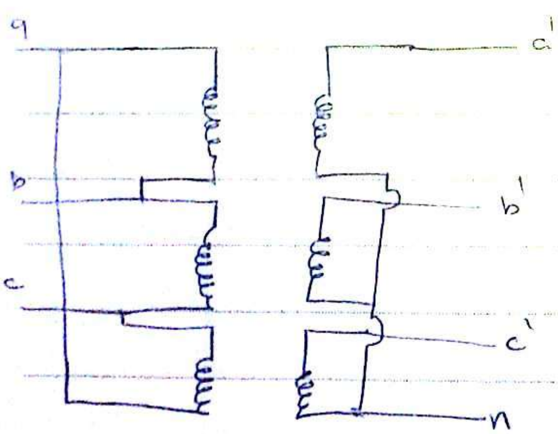
$V_{LP} = V_{\phi P}$

$V_{LS} = \sqrt{3}\, V_{\phi P}$

$\frac{V_{LP}}{V_{LS}} = \frac{1}{\sqrt{3}} a$

Y-Δ نفس حكي ال connection

but lag by 30°



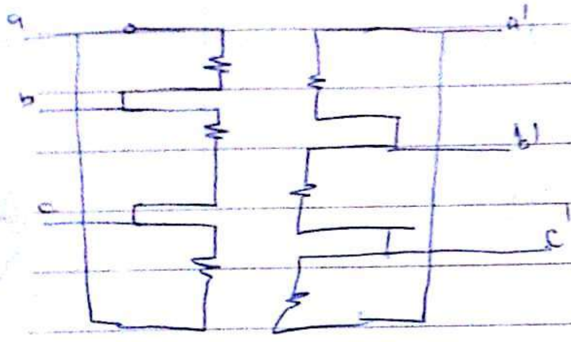
No

DELTA DELTA CONNECTION

$V_{LP} = V_{\phi P}$ $V_{LS} = V_{\phi S}$

$\frac{V_{LP}}{V_{LS}} = a$

has no problem with harmonics or Phase shift.



2.9. A 5000 kVA, 230/13.8kV single phase power transformer has a per unit resistance of 1 percent and per unit reactance of 5 percent. The open cct Performed on low voltage side of the transformer

$V_{o.c} = 13.8k$ $I_{oc} = 21.1$ $P_{oc} = 40.8k$

a) Find the equivalent circuit referred to the low voltage side of the transformer.

$a = \frac{230}{13.8} = 16.66$

$\phi = \cos^{-1} \frac{40.8k}{21.1 \times 13.8k} = \cancel{81}.94°$

$Y = 1.528 \times 10^{-3}$

$R_C = (1.528 \times 10^{-3} \cos \cancel{81.94})^{-1} = \cancel{4664.6337} \Omega = 8.08$ (71.99, 2 244)

$X_m = (1.528 \times 10^{-3} \sin 81.94)^{-1} = \cancel{660.97} \Omega = 2.65$ (71.83, 737)

$Z_{unit} = \frac{Z_{act}}{Z_{base}}$

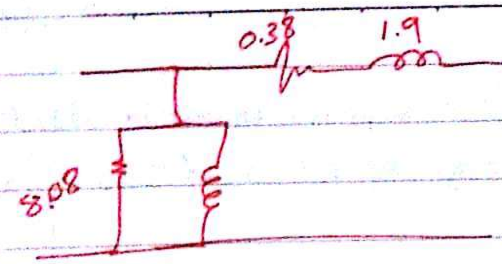
$Z_{base} = \frac{V_{base}}{I_{base}} = \frac{13.8k}{\frac{5000}{13.8k}} = 38.088$

$R_{eq} = (0.01)(38.088) = 0.38088$

$Z_{eq} = (0.05)(38.088) = 1.9044 J$

1

No.



b) the voltage on the secondary side is 13.8kV and the power is 4000 kW at 0.8 PF lagging Find VR ? efficiency?

$$\frac{V_P}{S} = 13.8 + \frac{4000k}{13.8k} \angle -\cos^{-1} 0.8 \, [0.38 + 1.9J]$$

$$I_S = \frac{5000k}{13.8k} \cos^{-1} 0.8$$

362.3 $\cancel{289.85}$ $\angle -36.87$

$$\frac{V_P}{S} = 14330 \angle 1.5 V$$

$$VR = \frac{14330 \; \cancel{14223.47} - 13800}{13800} = 3.84\% \; \cancel{3.868}$$

$$\text{efficiency} = \frac{4000k}{4000k + \frac{14330^2}{2124V} + (362.3)^2(0.38)} = 96\%$$

No.

A 1ϕ 13.8 KV single phase generator supplies power to a load through a transmission line. $Z_{load} = 500\angle 36.87$ and $Z_{line} = 60\angle 60$

[1] if the generator directly connected to the load (without transformer) what is the ratio of the load voltage to the general voltage? what is the transmission losses of the system??

$$I = \frac{13800}{500\angle 36.87 + 60\angle 60} = 24.83\angle -39.3$$

$$\text{Voltage line} = 24.83\angle -39.3\ (500\angle 36.87)$$
$$= 12417.28\angle -2.43$$

$$\text{ratio} = \frac{12.41728\,k}{13.8\,k} = 0.89$$

$$\text{losses} = 30\,(24.83)^2 = 36994.739 \text{ watt}$$

[2] efficiency: $\frac{246611.56}{265107.927} = 93$

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مراجعة بسيطة لمادة الدوائر الكهربائية :-

Resistance [المقاومة] → هي مقاومة جزيئات المادة لمرور التيار الكهربائي فيها

$v = I R$ $R [\Omega]$

Inductance [المحاثة -] DC short cct (بتخزن الحركة في التيار) .

AC $X = WL$ $[\Omega]$

Impedance [Z] ,

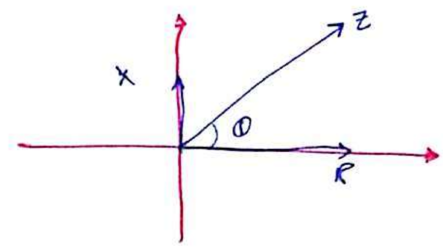
polar form . $\underbrace{Z}_{\text{magnitude}} \angle \theta \rightarrow$ angle

Rectangular form . $R + \underset{90}{J} X$

R ↓ مركبة سينية

J ↓ او [illegible] i

X ↓ مركبة صادية



power

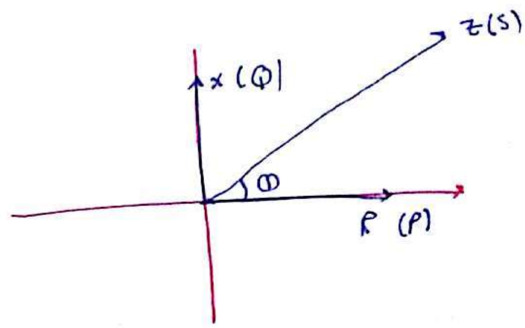
DC → $P = vI$, I^2R , $\frac{V^2}{R}$.

AC →

[1] Apperant Power $(S) = vI$ [VA] .
القدرة الظاهرية

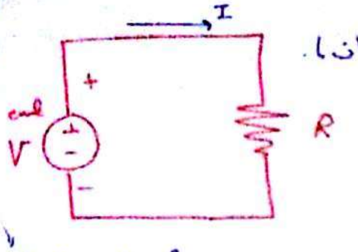
[2] Active Power $(P) = VI\cos\theta$ [WAtt] .
Average , Real

[3] Reactive Power $(Q) = VI\sin\theta$ [VAR] .



Type of machines:-

1) Electrical circuits:

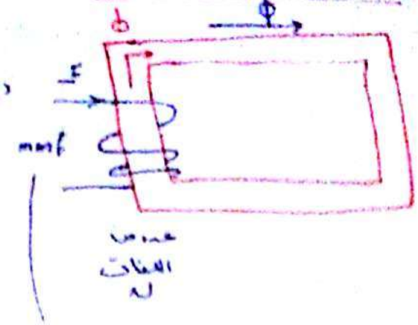


دع بما ينشأ تيار (التيار هو تدفق الالكترونات).

$I = \frac{V}{R}$

$R = \frac{l}{\sigma A}$ — l: length, A: area, σ: conductivity

2) magnetic circuits



magnatic motive force

$mmf = N I$

عندما يمر تيار في ملف ينشأ مجال مغناطيسي

$\phi = \frac{mmf}{R}$ → Relactance

$R = \frac{l}{\mu A}$ — l: length, A: Area, μ: Permeability

Magnatic Field Intensity (strength) H

$H = \frac{mmf}{l} = \frac{Ni}{l}$ [At/m]

Magnatic Flux density (B):

$B = \mu H$ [T]

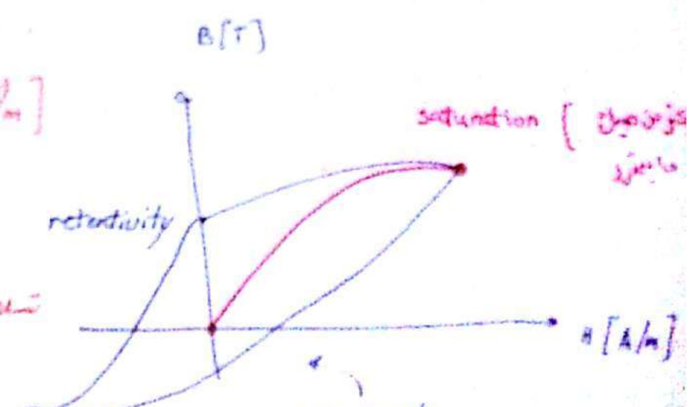
$\mu = \mu_r \mu_0$

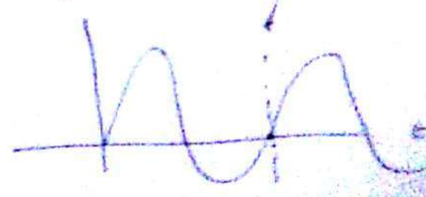
relative; μ_0 → air $[4\pi \times 10^{-7}]$

Flux = A · B [Wb]

A: area, B: Magnatic Flux density.

$A \cdot \mu \frac{Ni}{l} = \frac{mmf}{R} = \frac{mmf}{l/\mu A}$





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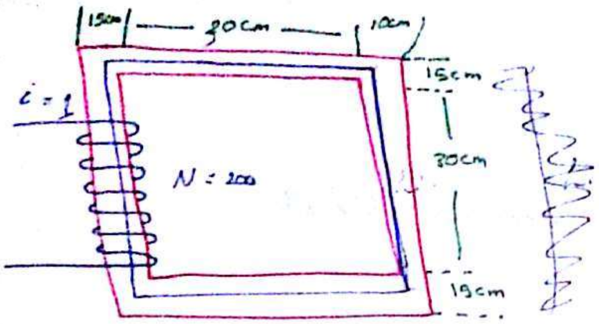
Example 1-1:



the depth of core = 10cm,

$\mu_r = 2500$, Flux ??

solution:

$$\phi = \frac{EEM}{R} = \frac{Ni}{\ell} \cdot A \cdot \mu$$

$$= \cancel{\frac{200 * 1}{210} * 2100 * 2500 * 4\pi \times 10^{-7}}$$

$$R = \frac{L}{\mu A}$$

مناخد النص لانو! حسب رح نتعامل مع كل الأضلاع بتمشي بالنص.

عرضها 10 ← $L_1 = \frac{15}{2} + 30 + \frac{15}{2} = 45 * 10^{-2}\, m.$

$$A_1 = 10 * 10 = 0.01 m^2$$

$$R_1 = \frac{0.45}{(2500 \times 4\pi \times 10^{-7})\, 0.01} = 14300 \text{ A turns/wb}$$

عرضها 15 ← $L_2 = \frac{10}{2} + 30 + \frac{15}{2} = 1.25 m$

$$A_2 = 15 \times 10 = 0.015 m^2$$

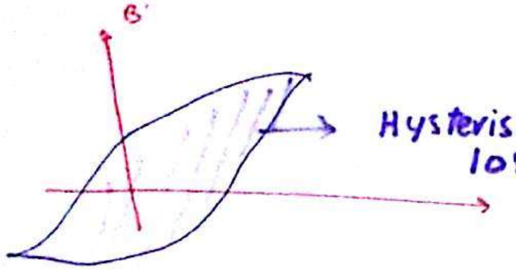
$$R_2 = \frac{1.25}{2500 \times 4\pi \times 10^{-7} \times 0.015} = 26525 \text{ Aturns/wb}$$

$$R = R_1 + R_2 = 14300 + 26525 = 40825 \text{ A.turns/wb}$$

$$\phi = \frac{200 * 1}{40825} = \boxed{4.89 * 10^{-3} \text{ wb.}}$$

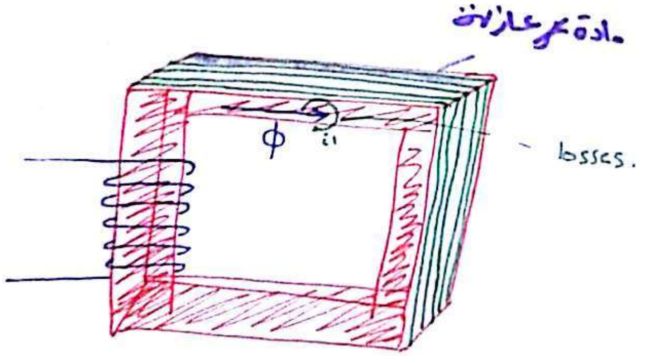
Magnetic losses:

1 Hysteresis losses :-



Hysterisis losess = Area ~~un~~ between the curve.

2 Eddy current losses



نتيجة تشتت الـ flux

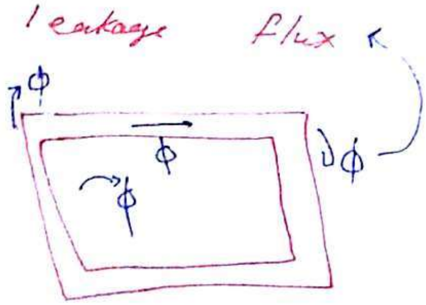
ينشأ تيارات صغيرة لولبية

ولمنع حدوث هذه الظاهرة نعمل

هذه الشريحة على شكل صفائح فالتيار عابر

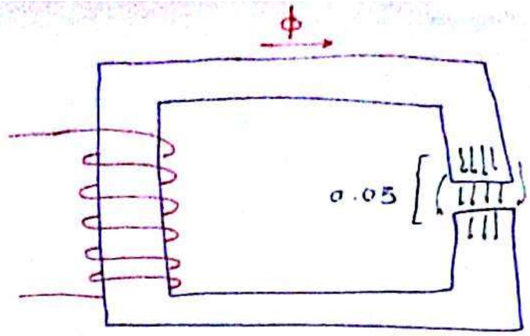
بسبب المجال بوجود مادة عازلة

3 leakage flux



لأنوا الـ flux عبثي بجز كاملها

Example 1-2



$l_c = 40cm$, air gap $= 0.05cm$

$A_c = 12cm^2$

$\mu_r = 4000$

Air gap ~ 105% A_c

find R ??

solution

الفراغ → $A\uparrow$ → مستخدم μ_0

الصلب → AL → $\mu_r \mu_0$

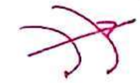
$$R_{core} = \frac{L_{core}}{\mu_r \mu_0 A_{core}} = \frac{0.4}{4000 \times 4\pi \times 10^{-7} \times 0.12 \times 10^{-2}} = 66314.55962 \text{ A.turns/wp}$$

$$R_{air} = \frac{0.05cm}{4\pi \times 10^{7} \times 1.05 \times 0.0012} = 3157836l \text{ A.turns/wp}$$

$$R = R_{air} + R_{core} = 3164467 6.28 \text{ A turns/wp}$$

Four electronagnetic Principles:

[1] A current cyrring wire produce a megnatic field $\vec{M}$



تحديد المجال حسب قاعدة اليد اليمنى
اتجاه التيار
المجال

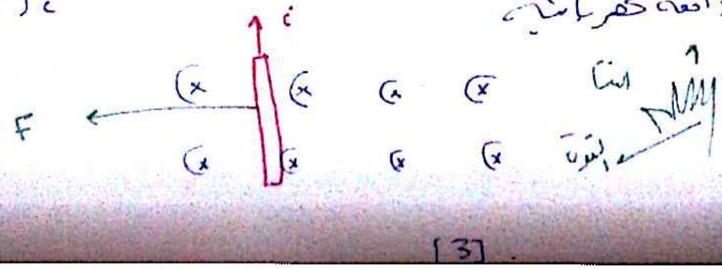
[2] a time changing magnatic flux produce an emf

$$emf = -\frac{d\phi}{dt}$$

لأنها القوة تعاكس المجال المغناطيسي

[3] Motor Action سلك يحمل تيار موجود داخل مجال مغناطيسي تتولد قوة ناتجة كهربائية

$\vec{F} = (\vec{l} \times \vec{B})\, i$

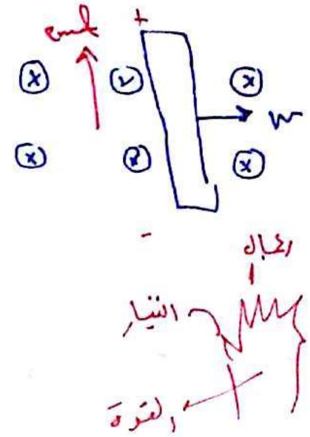


4 Generator Action

$\vec{E} = (\vec{v} \times \vec{B}) \vec{l}$

سلك بدنا نحركو بمجال مغناطيسي

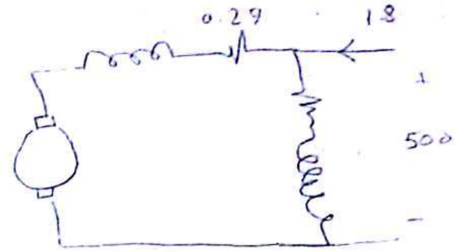
بنشأ فيه تيار



بعضها بتجاوب نحسب المقاومات والمفاعلات للتوازن

Example : A 500 V, 50 b.hp (37.3kW), 1000 rpm shunt DC motor has no full load an efficiency of 90 %. the armature resistance is 0.24 Ω and there is a total voltage drop of 2V at the brushes the field current is 1.8A.
① full-load line current ② full load Torque in Nm ③ total resistance in motor. starter to limit the starting current to 1.5 times the full load.

solution:



$$\frac{P_{output}}{P_{input}} = 90\%$$

~~Poutput = 90% × 37.3×10^3 = 33.570 kW~~

$$\frac{373000}{90\%} = \boxed{41.444 kW}$$

total current $P = V * I$

$41.444 = 500 * I$

(i) $\boxed{I = 82.8 \simeq 83A}$

$I_L = 83 - 1.8 = \boxed{81A}$

(ii) $\tau = k\phi i$

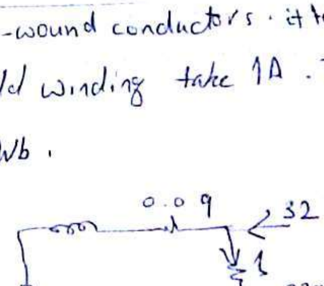
$\tau = \frac{E_a i}{\omega} = 356.18$ N.m

(iii) $500 = 2 + (0.24+R)(\cancel{82.84}\ 82.8 \times 1.5 - 1.8)$

498 121.95

$R = 3.8436\ \Omega$

Example: A 4pole, 220V shunt motor has 540 lap-wound conductors. it take 32A from main supply and develop 7.5 h.p (5.595kW). The field winding take 1A. The armature Resistance is 0.09 Ω and the flux per pole is 30mWb.
① speed ② torque.



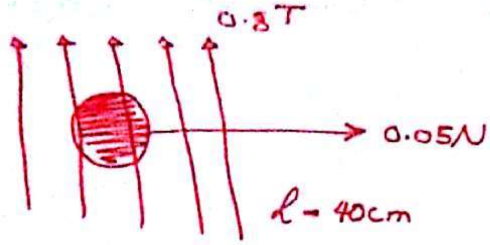
$I_L = 31A$ at starting. $\phi = 30 \times 10^{-3}$

$E_a = k\phi\omega n$

$\frac{\phi z n}{60}\left(\frac{P}{A}\right)$

$220 = 31(0.09) + E_a$ $E_a = 217.21 = k(30 \times 10^{-3})\omega n$

...ment mot.



Torque

$130 = 122.4 + 0.2I$

$I_a = 38$

$\tau = 37 N.m$

Find i ?

$0.05 = i(\cancel{40}\, 0.4 \times 0.8 \sin 90)$

16mA out of the page

Example: separately excited dc motor is rotated at 1000rpm.

under no load at 1000rmp

I_F	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
V_T (V_A)	0	30	60	85	102	115	124	130	134

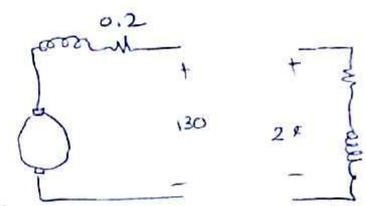
, $V_{field} = 24V$

R_F is adjustable.

$R_A = 0.2 \quad V_A = 130$

[1] field current at no load with 1000rmp.

at $V_T = 130 \quad I_f = 0.7A$



[2] The motor drives a load at $\boxed{1200rmp}$. calculate the armature voltage at 1200 rmp if the field Resistance $R_F = 60\Omega$.

$I_F = \frac{24}{60} = 0.4$

$E_a = k\phi\, 1200$

$102 - 0.2 = k\phi\, 1000$

$E_{1200} = E_{1000} \frac{1200}{1000}$

$E_a = 122.4$

$E_a = k\phi\, wn$

$\frac{E_a = k\phi\, 1200}{102 = k\phi\, 1000}$ $\boxed{E_a = 122.4}$ ~~$V_T = 122.4 + 0.2 I_L$~~

$122.4 = k\phi \cdot 1200 \times \frac{2\pi}{6}$

$k\phi = \cancel{0.102}$
0.974

$E_a = 0.974 \times 1200 \frac{2\pi}{60}$

$= 122.4$

[3] tourqe for above condition ~~$\tau = \frac{E_a I}{\omega} = \frac{122.4 \times I}{1200}$~~ $\tau = 122.4$

[4] motor supplies mechanical load at 4000W at 1450 rmp the mechanical losses are 160W calculate the efficiency

$P_{con} = 4000 + 160 = 4160$

~~$\frac{4000 - 160}{4000}$~~ $= 96\%$

$(V_T = E_a + I_a R) I_a$

~~416~~ $V_T I_a = 4160 + I_a^2 R$

efficiency $\frac{4000}{4000 + 160}$

$I_a = 33.79$

$130 = 0.2(33.75) + E_a$

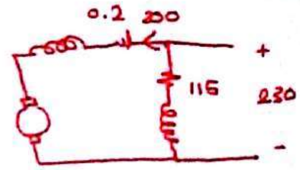
$E_a = 123.25$

A 230 V, 10 hp dc shunt motor delivers power to a load at 1200 r/min.
$I_a = 200\,A$, $R_a = 0.2\,\Omega$, $R_f = 115\,\Omega$, rotational losses are 500 W, load tourqe??

Solution

$T = k\phi\, i$

$T = k\phi \times 200$ $\qquad k\phi = \frac{E_a}{\omega} = \frac{230 - 0.2(200)}{1200}$



$P = 7,460\ kWatt$

$230 = E_a + 40 \qquad E_a = 190$

$P = 190 \times 200 = 38000 - 500$

$P = 37500$

$$T = \frac{37500}{1200 \times \left(\frac{2\pi}{60}\right)} = 298.41$$

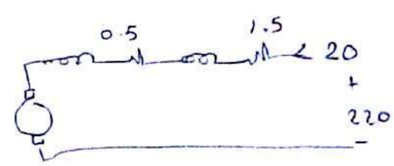
20

---

series-connected DC motor has an $R_a = 0.5\,\Omega$ $R_f = 1.5\,\Omega$ driving a certain load at 1200 rpm, the current drawn by the motor is 20 A from the voltage source 220 V. The rotational losses is 150 W. find efficiency.

$220 = 20(1.5 + 0.5) + E_a$

$E_a = 180$



$P = 180 \times 20 = 3600$

$$P = \frac{3600 - 150}{\cancel{3600}\ 4400} = \cancel{95\%}\ 78.404$$

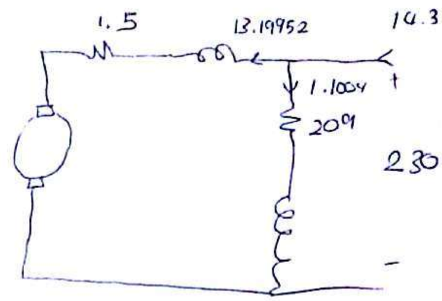
5 hP, 1800 rpm, 230 V_{DC}, shunt excited motor with circut model resistances R_f = 209 Ω R_a = 1.5 ohm (Pmech losses = 0W).

1 rated Tourqe .

$\tau = k\phi i$

$= \frac{E_a i}{\omega} = \frac{5 \times 746}{1800} = 19.8$ N.m

2 terminal current 14.3A while supply with rated voltage but driving less than the rated Load, determine the mechanical Power in hP and operational efficiency.



$P = \tau\omega$

$k\phi\ i \times 1800$

$\frac{E_a i}{\omega} \times \omega$

$13.19952\ (230 - 1.5(13.19952)$

2,774 kwatt

$\frac{P_{output}}{P_{input}} = \frac{2774}{5 \times 746} = 74.36\%$

---

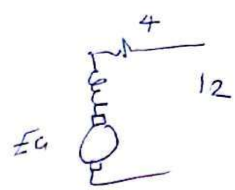
500 V, 37.3kW, 1000rmp DC shunt motor has an full load efficiency of 90%

$R_A = 0.24\ \Omega$ voltage drop 2 $I_f = 1.8$.

12V permenant DC-Motor with $R_a = 4\Omega$, speed = 2700rpm

I_C = 300mA rated voltage

1 tourqe $\tau = \frac{E_a i}{\omega}$



$\frac{10.8 \times 0.3}{2700}$

11.45×10^{-3}

$12 = 4 \times 0.3 + E_a$

$E_a = 10.8$

1-21 $\boxed{P\ 63}$

$\boxed{1}$ inital Force &. / initial current

→ initial current $= \frac{vB}{R} = \frac{100}{0.25} = 400\ A.$

initiall Force $= l(i \times B)$

$1(400 * 0.5 \sin 90) = 200N \rightarrow$ to the right.

$\boxed{2}$ $e_{ind} = vBl$ no load $v_{ind} = vB$

$100 = v_6 * 0.5 \quad v = 200\ m/s$

$\boxed{3}$ opposite direction → motor

$F = 25N$

$25 = i * B \quad \boxed{i = 50A}$

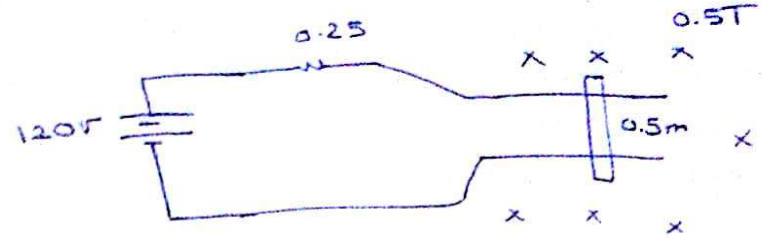
$50 = \frac{vB - e_{ind}}{0.25} \quad e_{ind} = 87.5$

$e_{ind} = v_6 Bl$

$87.5 = v_6 \times 0.5 \quad v_6 = 175 m/s$

$\eta = \frac{P_{output}}{P_{input}} = \frac{25 * 175}{50 * 100} = \frac{4375}{5000} = 87.5$

1-22 P $\boxed{64}$



$\boxed{1}$ opposite $\rightarrow$ motor

$F = 20$

$$\frac{120 - v_{eind}}{0.25} = i \qquad 20 = i \times 0.5 \times 0.5 \quad i = 80$$

$$\frac{120 - e_{ind}}{0.25} = 80$$

$$e_{ind} = 100 = v \times 0.5 \times 0.5$$

$$\boxed{v = 400 m/s}$$

$\boxed{2}$ $B = 0.45$

$F = \cancel{0.45} \downarrow$ $v \downarrow$ $\qquad v_{ss} = \frac{120}{0.45 \times 0.5} = 533.33 m/s$

$\boxed{3}$ $vB = 100$ $\qquad V_{ss} = \frac{100}{0.45 \times 0.5} = 444.44 m/s$

$\boxed{4}$ by decresing or increase the voltage and Flux density.

1.23 $\boxed{P\ 64}$

$\boxed{1}$

$\boxed{2}$ $F = 30N$ $B = 0.3$ 0.5 0.05

$30 = i\ 0.3 \times 0.5$

$i = 200 A$

$200 = \frac{120 - e_{ind}}{0.25}$

$e_{ind} = 70$

$70 = v \times 0.5 \times 0.3$

$v = 466.66\ m/s$

$30 = 0.5 \times 0.5\ i$

$i = 120$

$120 = \frac{120 - e_{ind}}{0.25}$

$e_{ind} = 90$

$90 = v \times 0.5 \times 0.5$

$v = 360\ m/s$

$30 = 0.5 \times 0.05\ i$

$i = 1200$

$1200 = \frac{120 - e_{ind}}{0.25}$

$e_{ind} = -180$

$-180 = v \times 0.05 \times 0.5$

$v = -7200$

no - load

$B = 0.5$

v $120 = 0.5 \times 0.5\ v$ $v = 480 m/s$

$30 = i \times 0.5 \times 0.5$ $i = 120$

$v = 360\ m/s$

$120 = B \times 0.5 \times 360$ $B = 0.66\ T$

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The Hashemite University
Faculty of Engineering
Course Syllabus

Course Title:	Electrical Machines	**Course Number:**	110405323
Department:	Department of Mechatronics	**Designation:**	Compulsory
Prerequisite(s):	110409203		
Instructor:	Eng. Fadwa Momani	**Instructor's Office:**	E3115
Instructor's e-mail:	Fadwamomani@yahoo.com, Engfadwa Momani (facebook account)		
Office Hours:	Announced on the office door		
Time:	10:40 -11:50 (Sun→ Thu)	**Class Room:**	E2023

Course description: This course introduces the basic principles of electrical machines and energy conversion. Principles and operation of Single and three phase transformers are also introduced. The principles, operation, key characteristics, and application of DC motors (e.g., bush types, brushless type, and servo type), AC motors (e.g., single and three phase), and special purposes motors (e.g., stepper motors) are also presented.

Textbook(s): Stephen Chapman: "Electric Machinery Fundamentals", 5th edition, McGraw Hill, 2012.

Other required material:

1. George Mcpherson, "An Introduction to Electrical Machines and Transformers," Wiley: New York, 1981/1990.
2. Charles Hubert, "Electric Machines: Theory, Operation, Applications, Adjustment, and Control," Pearson Education: Delhi, 2nd Ed, 2002.
3. Smarajit Ghosh, "Electric Machines," Pearson Education: Delhi, 2005.
4. Sayed Naser, "Handbook of Electrical Machines," McGraw-Hill: New York, 1987.
5. Sayed Naser, "Electrical Machines and Electromechanics," Schaum's outline series , 2nd Ed, 1998.

Course objectives:

The student shall be able to:

1. Obtain mathematical models, estimate, and analyze the performance characteristics of transformers and motors
2. Identify the best electrical motor for the desired application
3. Comprehend the impact of state-of-the-art electric machines in solving industrial problems

Topics covered:

1. Introduction to Machinery Principles (Chapter 1)
2. DC Machinery Fundamentals (Chapter 7)
3. DC Motors and Generators (Chapter 8)
4. Transformers (Chapter 2)
5. AC Machinery Fundamentals (Chapter 3)
6. Induction Motors (Chapter 6)
7. Single-Phase and Special-Purpose Motors (Chapter 9)

Class/laboratory schedule: 3 class sessions each week; 50 minutes each

Grading Plan:

First Exam	(30 Points)	wed 8/6/2016
Second Exam	(30 Points)	Tus 21/6/2016
Final Exam	(40 Points)	To be announced by the registrar

General Notes: Attendance is mandatory

Prepared by: Eng. Fadwa Momani **Date:** 24/5/2016

Electrical Machines Course Contents

Textbook: *Electric Machinery Fundamentals* by Stephen J. Chapman, McGraw Hill.

The contents covered in this course are presented during the semester as follows:

1. Introduction to Machinery Principles
2. DC Machinery Fundamentals
3. DC Motors and Generators
4. Transformers
5. AC Machinery Fundamentals
6. Induction Motors
7. Single-Phase and Special-Purpose Motors

In each required chapter, the sections covered are as follows during the semester:

Chapter	Sections		Excluded Titles
	4^{th} Version	5^{th} Version	
Introduction	1.1 – 1.8, 1.10	1.1 – 1.8, 1.10	
DC Motors	8.1, 8.4, 8.7, 8.8	7.1, 7.4, 7.7, 7.8	
	9.1 – 9.4, 9.6 – 9.7, 9.10, 9.17	8.1 – 8.7, 8.10, 8.17	
AC Circuits Review	1.9, 1.10, Appendix A	1.9, 1.10, Appendix A	
Transformers	2.1 – 2.3, 2.5, 2.7, 2.8, 2.10, 2.13, 2.14	2.1 – 2.3, 2.5, 2.7, 2.8, 2.10, 2.13, 2.14	▪ The Per-Unit System for Three-Phase Transformers ▪ The Transformer Phaser Diagram
AC Induction Motors	4.6 – 4.9	3.6 – 3.9	
	7.1 – 7.5, 7.9, 7.11, 7.13, 7.14	6.1 – 6.5, 6.11, 6.13, 6.14	
Single-Phase and Special-Purposes Motors	10.1 – 10.4, 10.6, 10.7	9.1 – 9.4, 9.6, 9.7	▪ The Double-Revolving-Field Theory of Single-Phase Induction Motors ▪ The Cross-Field Theory of Single-Phase Induction Motors ▪ Reluctance Motors ▪ Hysteresis Motors