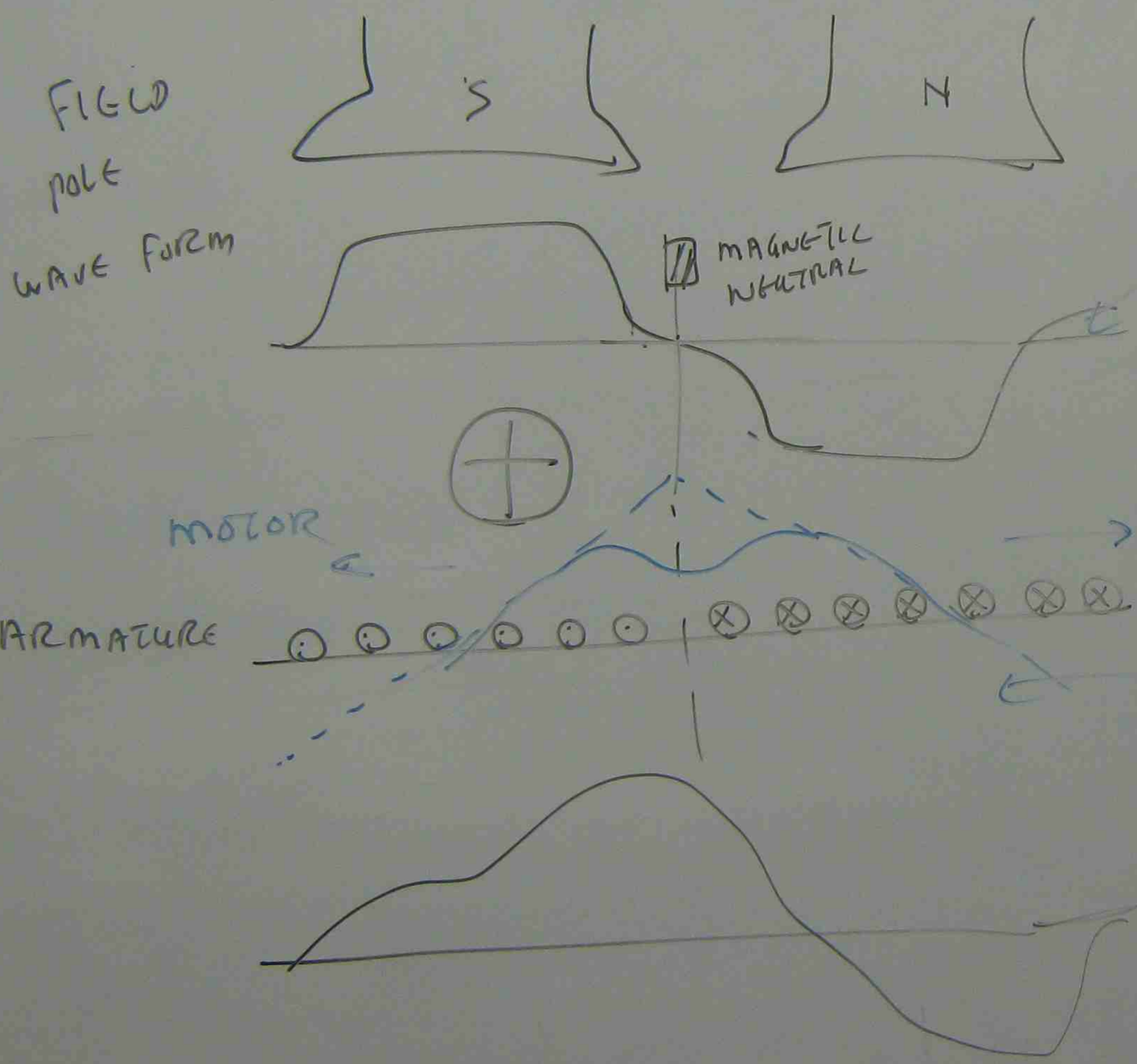
MAGNETIC ACTION OF ARMATURE FIELD DISTORTION



ARMATURE REACTION

- DEMAGNETIZING FLUX — ARMATURE FLUX OPPOSES MAIN FLUX
- CROSS MAGNETIZING FLUX — ARMATURE FLUX CROSSES MAIN FLUX

$$\text{CROSS MAGNETIZING AMP-TURNS/POLE} = \frac{r\, z\, I_a}{2a\, P}$$

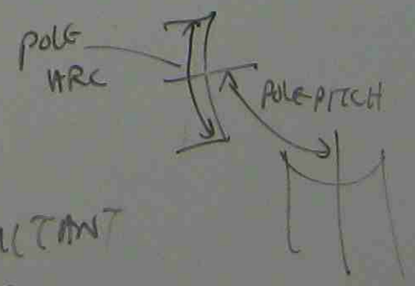
$$r = \frac{\text{POLE ARC}}{\text{POLE PITCH}}$$

z = ARMATURE CONDUCTORS

I_a = ARMATURE CURRENT

a = NO. ARMATURE PARALLEL PATHS

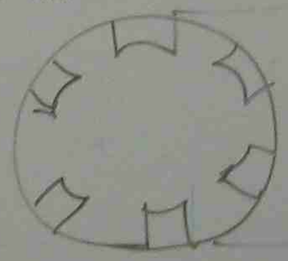
p = NO. OF POLES.



RE FLUX
AIN FLUX
E FLUX
MAIN
MATURE
DUCTORS
MATURE
URRENT
MATURE
LLEL
THS
POLES.

EXAMPLE 5.1 (REV)

AN ARMATURE 0.5 metres DIAMETER of 6 POLE LAP WOUND GENERATOR HAS 378 CONDUCTORS, CARRIES 800 AMP AND HAS A POLE ARC 0.17m - CALCULATE CROSS MAGNETIZING ARMATURE REACTION AMPERE TURNS.



CIRCUMFERENCE = πD

$= 3.1416 \times 0.5$

$$\gamma = \frac{\text{POLE ARC}}{\text{POLE PITCH}} = \frac{0.17}{\frac{3.1416 \times 0.5}{6}}$$

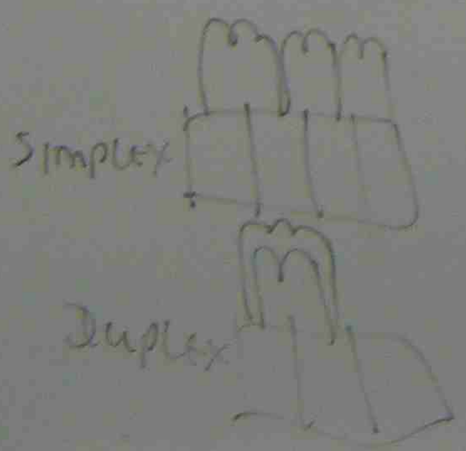
$= 0.65$

$$\text{CROSS MANGNETIZING AMP-TURNS/POLE} = \frac{\gamma z I_a}{2ap} = \frac{0.65 \times 378 \times 800}{2 \times 6 \times 6} = 2740 \text{ AT/pole.}$$

a = ARMATURE PARALLEL PATH = 1 (SIMPLEX LAP) $\times$ NO of POLES $= 1 \times 6$

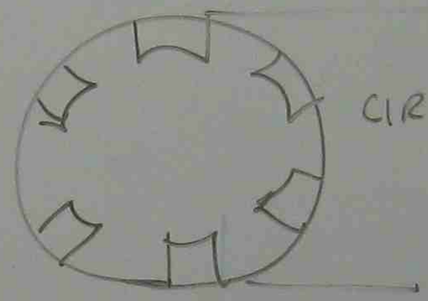
$= 6$

2 — DUPLEX LAP.



EXAMPLE 5.1 (REV)

AN ARMATURE 0.5 metres DIAMETER of 6 POLE LAP WOUND GENERATOR HAS 378 CONDUCTORS, CARRIES 800 Amp AND HAS A POLE ARC 0.17m - CALCULATE CROSS MAGNETIZING ARMATURE REACTION AMPERE TURNS.



CIRCUMFERENCE = πD

$= 3.1416 \times 0.5$

$$\gamma = \frac{\text{POLE ARC}}{\text{POLE PITCH}} = \frac{0.17}{\frac{3.1416 \times 0.5}{6}}$$

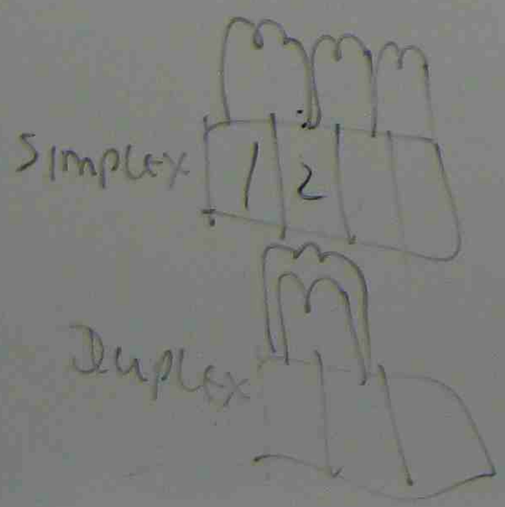
$= 0.65$

$$\text{CROSS MANGNETIZING AMP-TURNS/POLE} = \frac{\gamma z I_a}{2ap} = \frac{0.65 \times 378 \times 800}{2 \times 6 \times 6} = 2740 \text{ AT/pole.}$$

a = ARMATURE PARALLEL PATH = 1 (SIMPLEX LAP) $\times$ NO of POLE $= 1 \times 6$

$= 6$

2 — DUPLEX LAP.



WAVE $a = 2m$ ← SIMPLEX = 1, DUPLEX = 2

(a) $T = \frac{60\,P}{2\pi\,N_{FL}} = \frac{60 \times 3.75\times10^{3}}{2\times3.1416\times1750} = 20.4$ N-m

(b) $N_{FL} = \frac{V_t - \text{BRUSH DROP} - I_a R_a}{K\phi a}$

$1750 = \frac{230 - 2 - 18\times0.3}{K\phi a}$

$K\phi a = 0.1273$

$\%$ FLUX REDUCTION $\times K\phi a = \frac{V_t - \text{BRUSH DROP} - I_a R_a}{N}$

$0.96\times0.1273 = \frac{230-2-I_a\times0.3}{1750}$

$0.96\times0.1273\times1750 = 228 - 0.3I_a$

$I_a = \frac{228 - 0.96\times0.1273\times1750}{0.3}$

$I_a = 46.7$ Amp

(c) $\frac{T_1}{T_2} = \frac{K\phi_1 I_1}{K\phi_2 I_2}$

$\boxed{K = 0.159\times\frac{Z\,P}{a}}$

$\frac{20.4}{T_2} = \frac{\phi_1 \times 18}{0.96\phi_1\times46.7}$

$\frac{20.4}{T_2} = \frac{18}{0.96\times46.7}$

$T_2 = \frac{20.4\times0.96\times46.7}{18}$

$= 50.56$ N-m

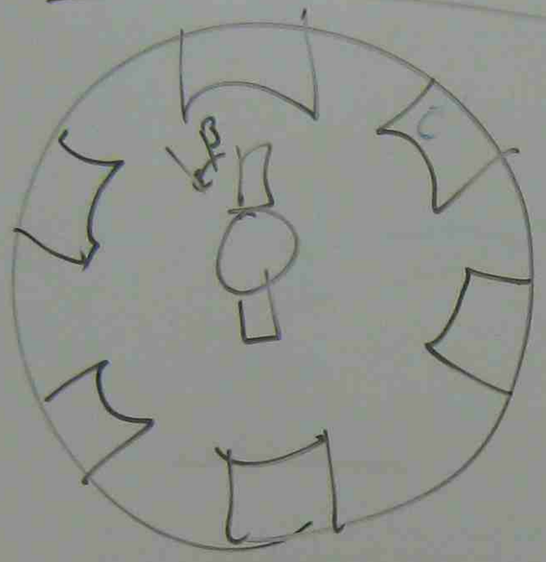
POWER $= \frac{2\pi NT}{60} = \frac{2\times3.1416\times\frac{1750}{0.96}\times50.56}{60}$

$\frac{E_{g1}}{E_{g2}} = \frac{\phi_1 N_1}{\phi_2 N_2}$

$1 = \frac{\phi_1\times1750}{0.96\times N_2}$

$N_2 = \frac{1750}{0.96}$

BRUSH SHIFTING



→ TO REDUCE ARMATURE REACTION

BRUSH SHIFTING ANGLE

$$\text{DE MAGNETIZING AMP. TURNS/POLE} = \frac{\beta \, Z \, I_a}{360 \, a}$$

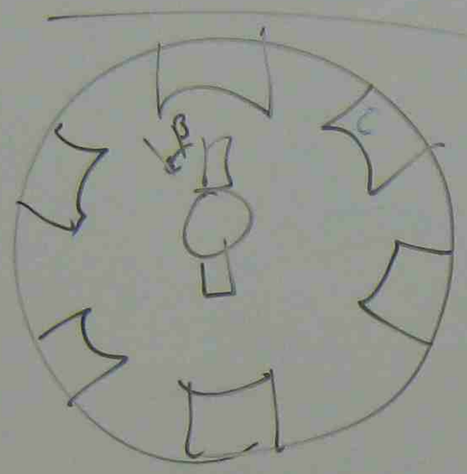
Z = No. of CONDUCTOR

I_a = ARMATURE CURRENT

a = ARMATURE PARALLEL PATH

$$\text{CROSS MAGNETIZING AMP-TURNS/POLE} = \frac{Z \, I_a}{2P}\left(\frac{360 - 2P\beta}{720}\right)$$

BRUSH SHIFTING



→ TO REDUCE ARMATURE REACTION

DE MAGNETIZING AMP. TURNS / POLE $= \dfrac{\beta \; Z \; I_a}{360 \; a}$

β = BRUSH SHIFTING ANGLE

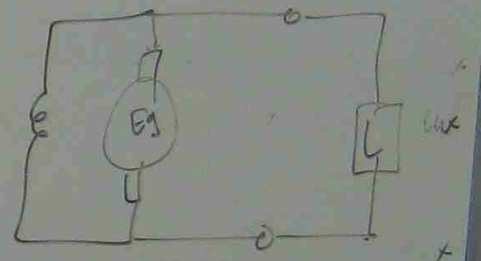
Z = NO. OF CONDUCTOR

I_a = ARMATURE CURRENT

a = ARMATURE PARALLEL PATH

CROSS MAGNETIZING

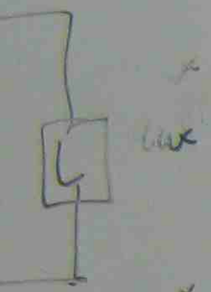
$$\text{AMP-TURNS / POLE} = \frac{Z \, I_a}{2P}\left(\frac{360 - 2P\beta}{720}\right)$$



$\% \text{ REGULATION} = \dfrac{E_g - V_{FL}}{V_{FL}} \times 100$

E_g = GENERATED VOLTAGE

V_{FL} = FULL LOAD VOLTAGE



- UFL
— x100
FL
OLTAGE
OLTAGE

Ex 6.2
P103

A 75 KW, 500V GENERATOR HAS 1S%

VOLTAGE REGULATION

CALCULATE (a) OPEN CIRCUIT VOLTAGE

(b) KW OUT PUT FOR TERMINAL VOLTAGE 510V.

$$4 = \frac{Eg - 500}{500} \times 100$$

$$\frac{4 \times 500 + 500}{100} = Eg = 520V$$

$$I_{FL} = \frac{75 \times 10^3}{500} = 150 \text{ Amp.}$$

$Eg = 520V \longrightarrow I_{fL} = 150 A$

$Eg = 510V \longrightarrow ? =$

$$I_{fL_2} = \frac{Eg - VFL_2}{Eg - VFL_1} \times I_{fL_1}$$

$$I_{510} = I_{520} \times \frac{520 - 510}{520 - 500}$$

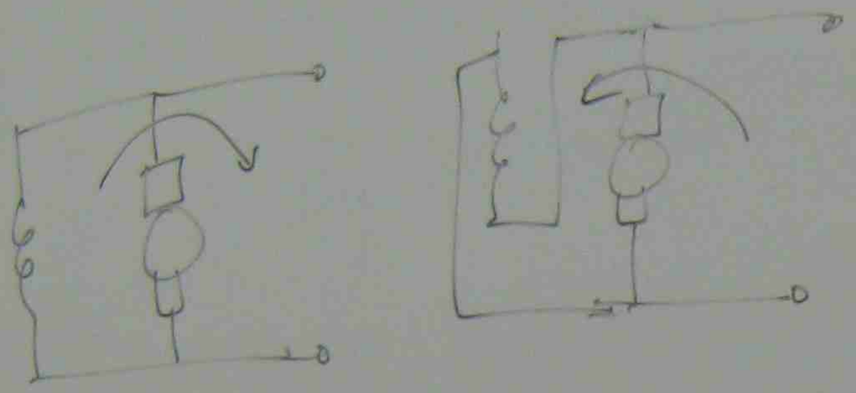
$$= 150 \times \frac{10}{20}$$

$$= 75A$$

OUTPUT = 75×510 V

$= 38250$W

$= 38.25$ KW.



REVERSE THE FIELD CONNECTION → REVERSE ROTATION OF DC SHUNT MOTOR

$E_g \propto \phi N$

$$\frac{E_{g_1}}{E_{g_2}} = \frac{\phi_1 N_1}{\phi_2 N_2}$$

EX 7.3 (Test 2)

PAGE 8 BOOK 2

MOTOR PARTICULARS 3.7 SKW, 230V

18 AMP 1750 RPM, $R_a = 0.3\Omega$

BRUSH DROP = 2V ON LOAD

CALCULATE

(a) FULL LOAD TORQUE

(b) INITIAL RUSH OF ARMATURE CURRENT & CORRESPONDING TORQUE AT THE INSTANT THE FIELD RHEOSTAT RESISTANCE IS INCREASED TO REDUCE THE FIELD FLUX TO 0.95 ORIGINAL VALUE

(c) FINAL ARMATURE CURRENT, SPEED, POWER CONSUMING.

$T \propto I_a^2$ T ↑



Advanced Diploma Electrical Technology 17908 – At Sydney Institute-Ultimo

Undertake Computations in Electrotechnology Environment
UEENEEE050A 5/8

Identify Effects of Energy on Machinery And Materials in Electrotech
UEENEEE040A 5/8

Provide Computational Sols to Power Eng Probs
UEENEEG047A 5/8

Solve Problems in Complex Multipath Power Cct
UEENEEG048A 5/8

Solve Problems in Complex POLYPHASE Power Cct
UEENEEG049A 5/8

Doc Hazards/Risks
UEENEEE003B

Parsonal Dev plan
UEENEEE038B

Solve Problems in Electromag Cct
UEENEEG001B 1.2

Solve Problems 1+3 Phase Low Volt Cts
UEENEEG002B 1.2

Select and arrange equipment for General Electrical Installations
UEENEEG007B 3

Solve Problems in Complex Multipath Circuits
UEENEEE025A 5/8

Computational Solutions to Basic Eng Problems
UEENEEE026A 5/8

Troubleshoot Amplifiers
UEENEEH013A 3

Provide Solutions to Single & Electronic Power Control
UEENEEH25B 4.5

Provide Solutions to Poly/Phase Electronic Power Control
UEENEEH28B 4.5

Solve Problems single path Cct
UEENEEE003B 1.2

Solve Problems DC Multipath Circuits
UEENEEE004B 1.2

Troubleshoot Frequency Dependent Circuits
UEENEEH014A 3

Troubleshoot Basic Amplifiers
UEENEEH030A 3

Troubleshoot DC Supplies
UEENEEHC11B 3

Repair Complex Power Supplies
UEENEEH036B 3

Rectify Faults in Analogue Cct & Control Systems
UEENEEH044B 4.5

Lay and Connect Cables for Multiple Access to Telecommunications Equipment
UEENEEF02B

Needs G008 From Trade

Diag /Rect Faults in Digital Subsystems
UEENEEH043B 3

Fabric Electrotech Components
UEENEEE002B 2.5

Fix/Secure Equip
UEENEEE005B 2.5

O H & S
UEENEEE001B

Use Diagrams and Manuals
UEENEEE007A 3

Lay/Terminate E.L.V. Cts
UEENEEE008A 3

Install/Setup Transducers/Sensors
UEENEEE001B 3

Repairs by replace Components
UEENEEH002A 3

Troubleshoot Digital Systems ---TBA---
UEENEEH012B 3

Assemble, Setup & Test PCs
UEED0002A 4

Use Engineering Software Appls
UUENEED004A 2.5

Develop Structured Programs
UEENEED027A 4

Develop Programs for PLCs
UEENEED007B 5.5

Solve Problems Pressure Measure
UEENEEE002B 3

Solve Problems Density/Level Meas
UEENEEE003B 3

Solve Problems Flow Measurment
UEENEEE004B 3

Solve Probs Temp Measurement
UEENEEE005B 3

Develop Programs for Industrial Control Systems Using High Level Languages
UEENEED009A 4.5

Develop and Verify Programs in SCADA Systems
UEENEED008A 4.5

Solve Problems in Process Controllers, Transmitters and Converters
UEENEEJ008B 6

After All Fault Finding at AQF3 achieved

After ALL CORE UNITS achieved

Compile/ Produce Electrotechnology Report
UEENEEE024B 5.5

After ALL TECHNICAL UNITS achieved

Manage Elctrical Projects
UEENEEG069B 6

Manage Risk in Electrotechnology Activities
UEENEEE011B 5

Plan Electrical Projects
UEENEEG070B 6

Design Strategies to address Sustainability Issues
UEENEEK032B 4.5

Design and develop Electronic/Computer Systems Projects
UEENEEH088B 5.5

implied

LEGEND:

Sydney Institute of TAFE, Ultimo	TITLE	REVISIONS			5
JOB NO: TBA	SCALE: N/A	Course Map - Working Version Advanced Diplomas of Electrical Engineering/Electrotechnology	1 28th April 2009 Rel 1		6
File Reference: File Name	REFERENCE		2		7
	DRAWN: J Fenton	CHECKED:	3		8
			4		9

Advanced Diploma Electronic Technology 17796 –
At Sydney Institute-Ultimo

Undertake Computations in Electrotechnology Environment
UEENEEE050A 5/6

Solve problems in Electronic Circuits
UEENEEH069B 2/3

Fabric Electrotech Components
UEENEEE002B 2,3

Fix/Secure Equip
UEENEEE005B 2,3

O H & S
UEENEEE001B

Assemble, Setup & Test PCs
UEEE0002A

Use Diagrams and Manuals
UEENEEE07A 3

Use Engineering Software Apps
UUENEED004A 2,3

Implied

Implied

Implied

Identify Effects of Energy on Machinery And Materials in Electrotech
UEENEEE046A 5/6

Solve Problems in Complex Multipath Circuits
UEENEEE025B 5/6

Troubleshoot Frequency Dependent Circuits
UEENEEH014A 3

Lay and Connect Cables for Multiple Access to telecommunications Equipment
UEENEEF02B

Setup and Config Basic DataComs
UEEF014B 3/4

Develop Programs for PLCs
UEENEED007B 3,4

Repairs by replace Components
UEENEEH002A 3

Implied

Solve Fundamental Probs in Electrical Sysytems
UEENEEG012B 5/6

Computational Solutions to Basic Eng Problems
UEENEEE026A 5/6

Troubleshoot Amplifiers
UEENEEH013A 3

Troubleshoot Basic Amplifiers
UEENEEH039A 3

Troubleshoot DC Supplies
UEENEEH011B 3

Troubleshoot Digital Systems
UEENEEH012B 3

Develop Programs for Industrial Control Systems using High Level Languages
UEENEED009A 4,5

Troubleshoot Oscillators
UEENEEH042B 3/4

Repair Complex Power Supplies
UEENEEH038B 3

Develop and Verify Programs in SCADA Systems
UEENEED008A 4,5

Implied

Implied

Solve Probs in Communications
UEENEEH046B 4,5

After All Fault Finding at AQF3 achieved

Diag /Rect faults in Digital Subsystems
UEENEEH043B 4

Develop Software Microcontroller Sys
UEENEEH043B 4

Electronic Risk/Haz
UEENEEE034B

Find/repair Microwave Amps
UEENEEH016B 3/4

Find and Repair Faults in Communication Sysyems
UEENEEH072B 3/4

Rectify Faults in Analogue Ccts & Control Systems
UEENEEH044B 4,5

Solve Problems in Process Controllers, Transmitters and Converters
UEENEEI006B 6

Personal Dev plan
UEENEEE038B

OR

Provide Solutions to Single ϕ Electronic Power Control
UEENEEH25B 4,5

Provide Solutions to PolyPhase Electronic Power Control
UEENEEH26B 4,5

After All technical Units achieved

Design Briefs Electrotech Projects
UEENEEE015B 5,6

Implied

Implied

Implied

Solve Electrotechnical Problems
UEENEEE029B 6

Manage Risk in Electrotechnology Activities
UEENEEE011B 6

Design and develop Electronic/Computer Systems Projects
UEENEEH088B 5,6

LEGEND:

Sydney Institute of TAFE, Ultimo	TITLE: Course Map - Working Version Advanced Diplomas of Electrical Engineering/Electrotechnology	REVISIONS			5
JOB NO: TBA	SCALE: N/A	1	28th April 2009	Rel 1	6
		2			7
		3			8
File Reference: File Name:	REFERENCE DRAWN : J Fenton CHECKED:	4			9

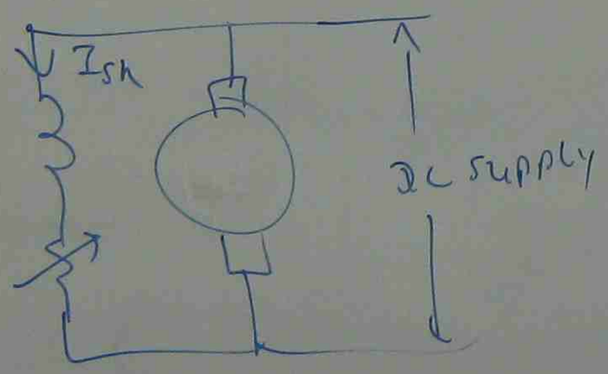
TORQUE SPEED RELATIONSHIP IN SERIES MOTOR

$$\text{TORQUE} = K \phi I_a$$

$\phi \uparrow \quad I_a \uparrow \quad T \uparrow$

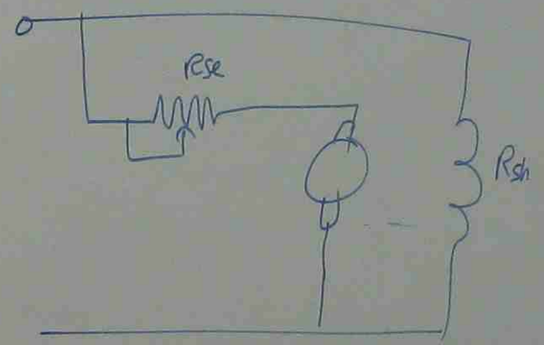
$$T = \text{Full load torque} = \frac{60P}{2\pi N}$$

P = No. of poles N = SPEED.



DC SHUNT MOTOR

I_{Sh} CHANGES → SPEED CHANGES



ARMATURE SPEED CONTROL BY SERIES RESISTANCE

REVISION 2.2

Ex 7.5

7.46 KW, 230V, 1750 rpm SHUNT MOTOR. ARMATURE RESISTANCE 0.35Ω. SHUNT FIELD RESISTANCE 62.2Ω.

(a) NO LOAD CURRENT IS 7.7 Amp

FULL LOAD EFFICIENCY 86%

BRUSH DROP 3V AT FULL LOAD, 1V AT NO LOAD

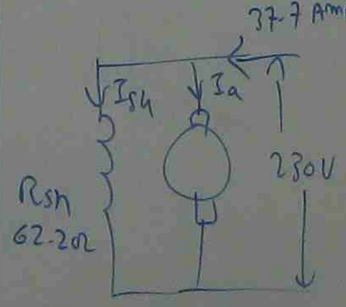
CALCULATE % REGULATION

(b) A 2.65Ω RESISTANCE IS PLACED IN SERIES WITH ARMATURE CIRCUIT. CALCULATE NEW SPEED % REGULATION, % POWER LOSS IN SERIES RESISTANCE IN RESPECT OF TOTAL POWER IN PUT.

$$I_{FL} = \frac{\text{OUT PUT POWER}}{\text{VOLTAGE} \times \text{EFFICIENCY}}$$

$$= \frac{7.46 \times 10^3}{230 \times 0.86}$$

$$= 37.7 \text{ AMP.}$$



$$I_{SH} = \frac{230}{62.2} = 3.7 \text{ Amp}$$

$$I_{a_{FL}} = 37.7 - 3.7 = 34 \text{ Amp}$$

FULL LOAD

$I_{a\,NL} = 7.7 - 3.7 = 4$ Amp

$N_{FL} = 1750$ rpm $N_{NL} = ?$

$I_{a\,FL} = 34$ Amp $I_{a\,NL} = 4$ Amp

$$\frac{E_{b_1}}{E_{b_2}} = \frac{\phi_1 N_1}{\phi_2 N_2}$$

$$E_{b_1} = E_{b\,FL} = V - [I_{a\,FL} \times R_a + \text{BRUSH DROP}]$$
$$= 230 - [(34) \times 0.35 + 3]$$

$$N_1 = N_{FL} = 1750$$

$$E_{b_2} = E_{b\,NL} = V - [I_{a\,NL} R_a + \text{BRUSH DROP}]$$
$$= 230 - [4 \times 0.35 + 1]$$

$$\phi_1 = \phi_2$$

$\therefore$

$$\frac{230 - [34 \times 0.35 + 3]}{230 - [4 \times 0.35 + 1]} = \frac{\cancel{\phi_1} \times 1750}{\cancel{\phi_2} \times N_{NL}}$$

$$N_{NL} = 1850 \text{ RPM}$$

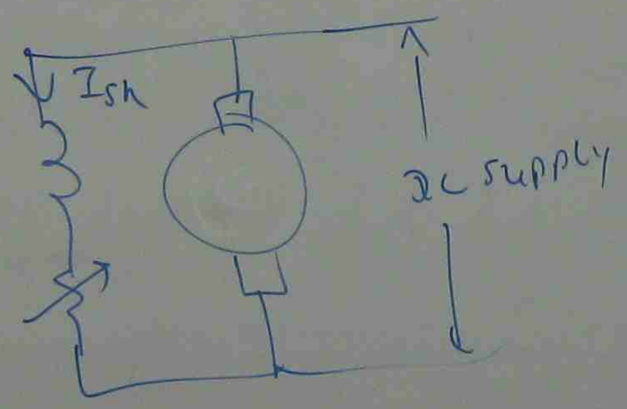
TORQUE SPEED RELATIONSHIP IN SERIES MOTOR

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$\phi \uparrow \quad I_a \uparrow \quad T \uparrow$

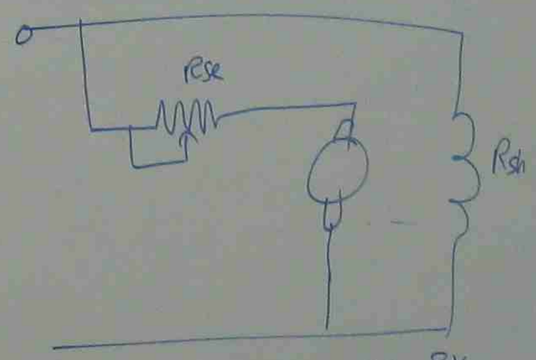
$$T = \text{FULL LOAD TORQUE} = \frac{60P}{2\pi N}$$

P = NO. OF POLES N = SPEED.



DC SHUNT MOTOR

I_{Sh} CHANGES → SPEED CHANGE



ARMATURE SPEED CONTROL BY SERIES RESISTANCE

REVISION 2-2

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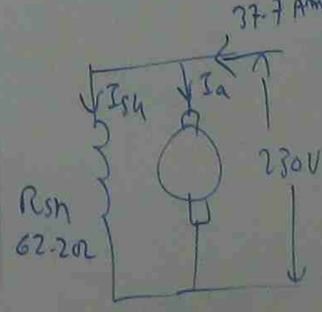
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$$= \frac{7.46 \times 10^3}{230 \times 0.86}$$

$$= 37.7 \text{ AMP.}$$



$I_{SH} = \frac{230}{62.2} = 3.7 \text{ AMP}$

$I_a = 37.7 - 3.7 = 34$ AMP

FL FULL LOAD

$I_{a\,NL} = 7.7 - 3.7 = 4$ Amp

$N_{FL} = 1750$ rpm $\quad N_{NL} = ?$

$I_{a\,FL} = 34$ Amp $\quad I_{a\,NL} = 4$ Amp

$$\frac{E_{b1}}{E_{b2}} = \frac{\phi_1 N_1}{\phi_2 N_2}$$

$E_{b1} = E_{b\,FL} = V - [I_{a\,FL} \times R_a + \text{BRUSH DROP}]$

$= 230 - [(34) \times 0.35 + 3]$

$N_1 = N_{FL} = 1750$

$E_{b2} = E_{b\,NL} = V - [I_{a\,NL} R_a + \text{BRUSH DROP}]$

$= 230 - [4 \times 0.35 + 1]$

$\phi_1 = \phi_2$

$$\frac{230 - [34 \times 0.35 + 3]}{230 - [4 \times 0.35 + 1]} = \frac{\phi_1 \times 1750}{\phi_2 \times N_{NL}}$$

$N_{NL} = 1850$ RPM

$E_{b2} = 230 - [4 \times 0.35 + 1]$

$N_{NL} = 1850$ rpm

$E_{b3} = V - [I_a R_a + \text{BRUSH DROP}]$

$= 230 - [34 \times (0.35 + 2.65) + 3]$

$$\frac{E_{b2}}{E_{b3}} = \frac{\phi_2 N_2}{\phi_3 N_3}$$

$$\frac{230 - (4 \times 0.35 + 1)}{230 - [34 \times (0.35 + 2.65) + 3]} = \frac{1850}{N_3}$$

$N_3 = 1020$ RPM

% SPEED REGULATION $= \frac{N_{NL} - N_{FL}}{N_{FL}} \times 100$

$= \frac{1850 - 1750}{1750} \times 100$

$= 5.7\%$

2.65Ω POWER loss $= I_a^2 \times 2.65\,\Omega$

$= (34)^2 \times 2.65$

$= 3060$ W

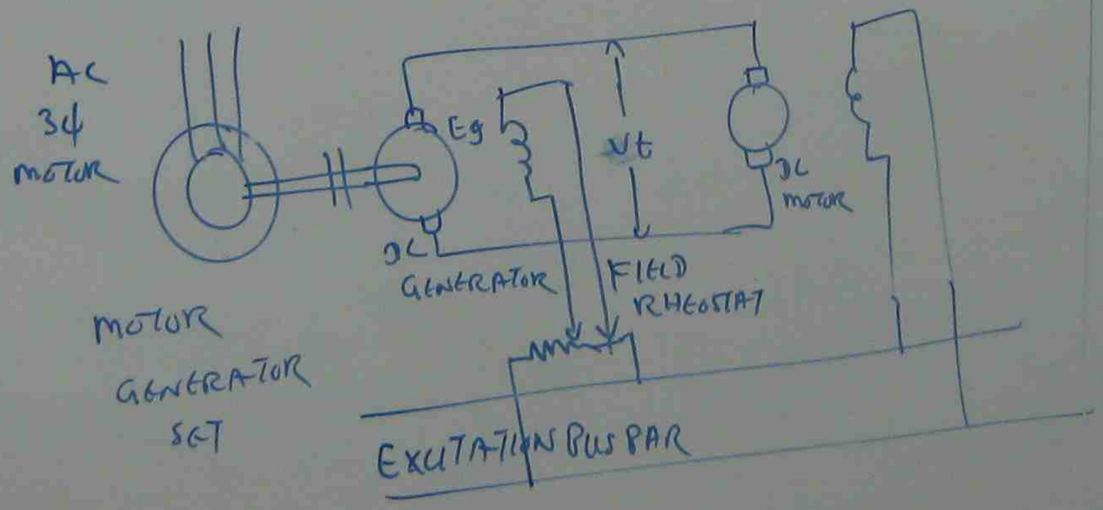
% of POWER INPUT $= \frac{3060}{230 \times 37.7} \times 100$

$= 39.2\%$

SPEED CONTROL, STARTING AND BRAKING METHODS FOR AC & DC MOTORS

SPEED CONTROL

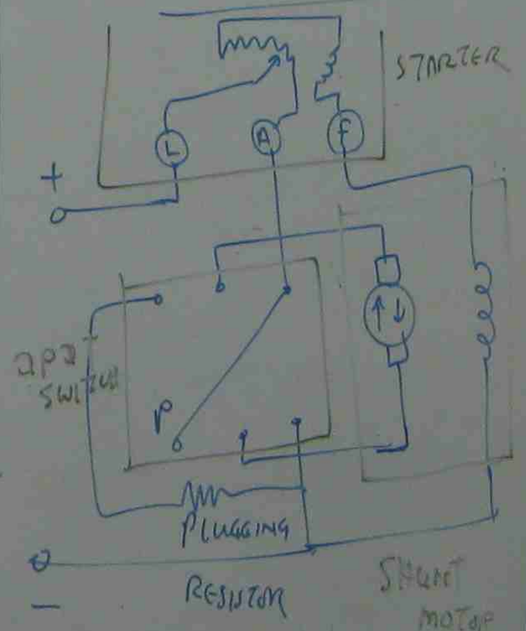
- AC
  - $N = \frac{120f}{P}$
  - AC → DC → PWM → AC MOTOR
  - VARIABLE SPEED DRIVE
- DC
  - SHUNT FIELD CURRENT FLUX
  - ARMATURE CURRENT FLUX
  - WARD LEONARD CONTROL



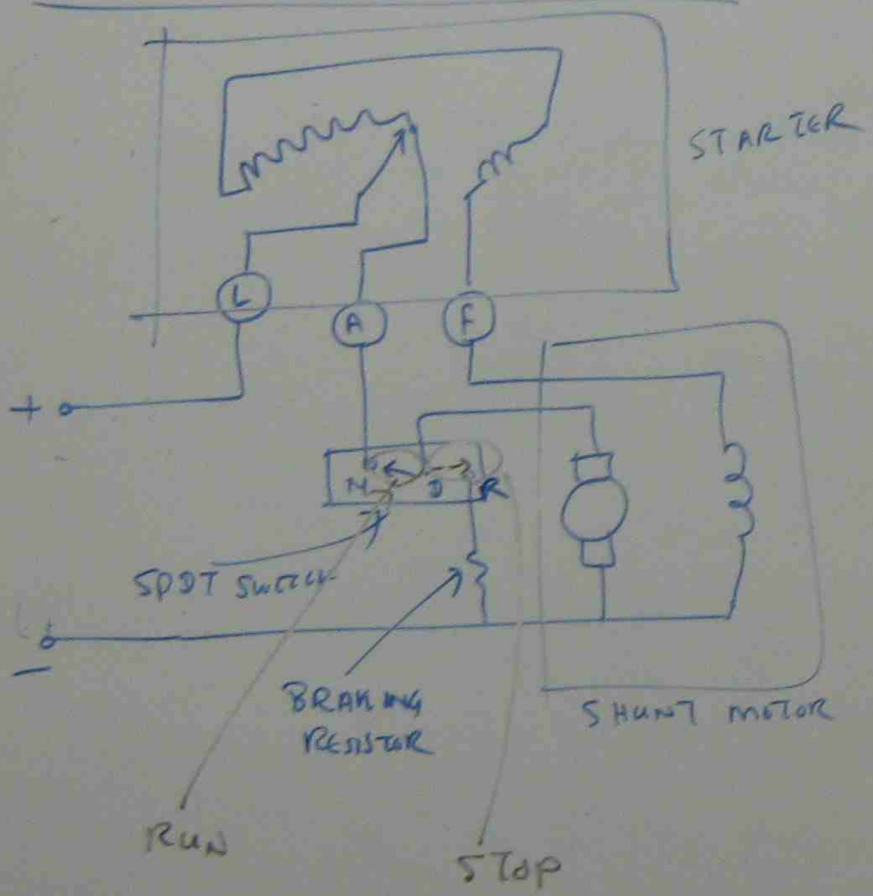
BRAKING

- AC
- DC
  - PLUGGING
  - DYNAMIC BRAKING
  - MECHANICAL BRAKE

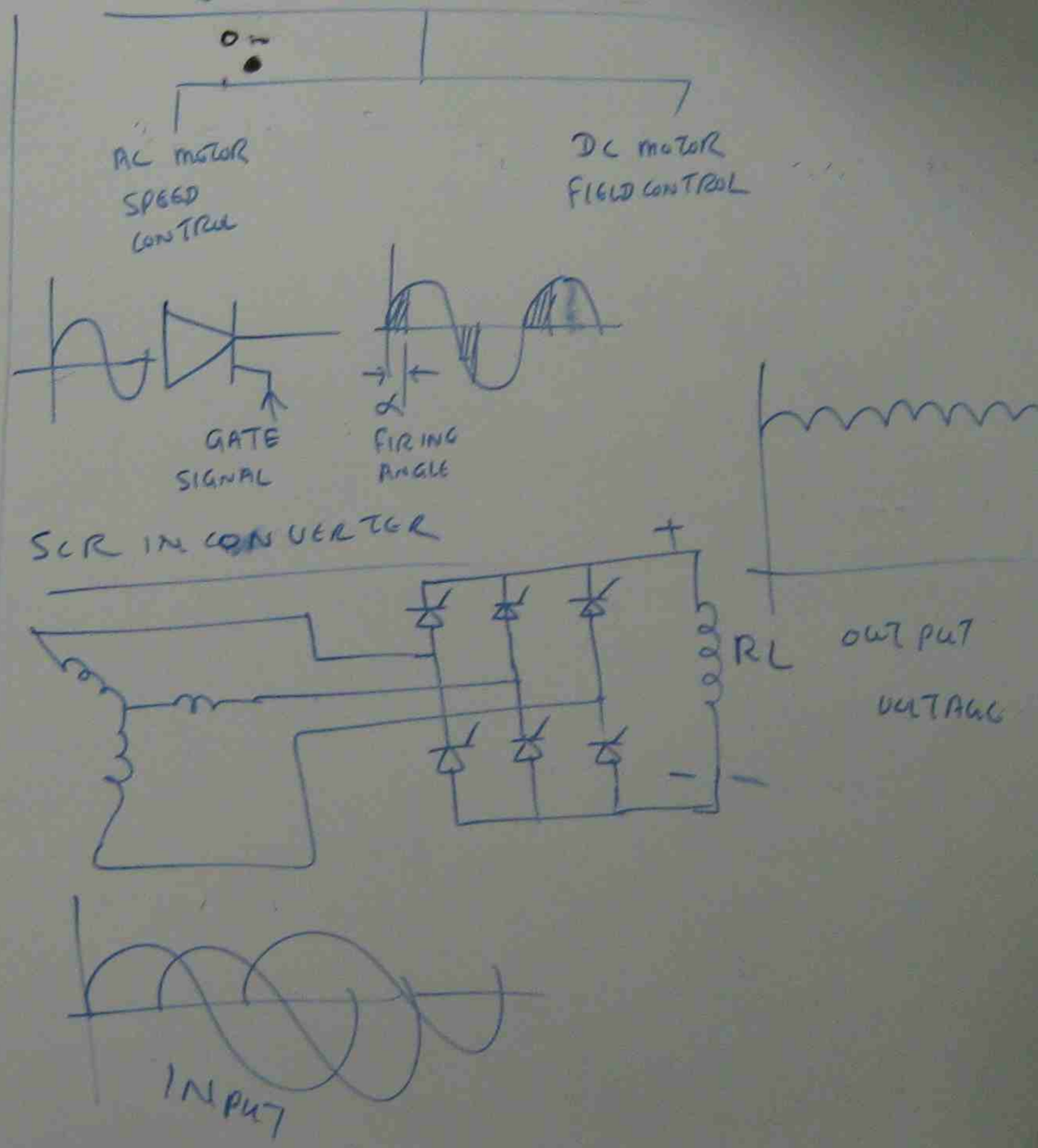
BRAKING BY PLUGGING



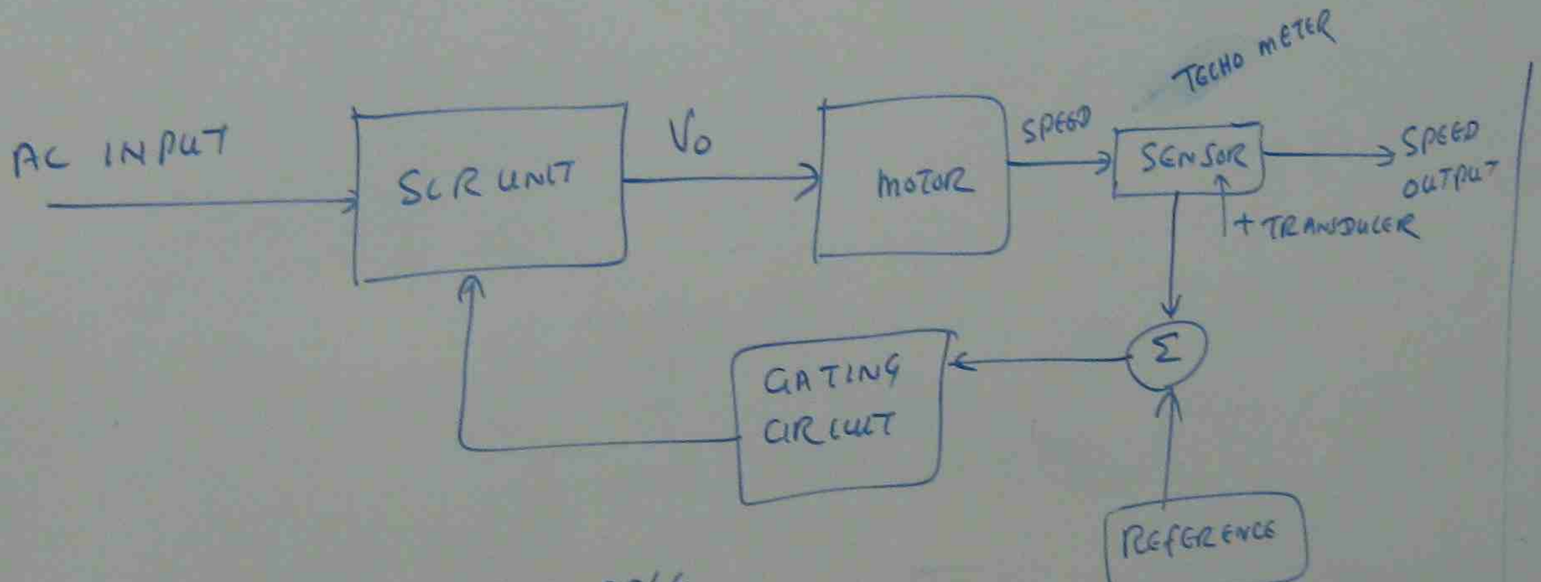
BRAKING BY DYNAMIC BRAKING



SCR (SILICON CONTROLLED RECTIFIER)



BLOCK DIAGRAM OF SCR CONTROLLED MOTOR

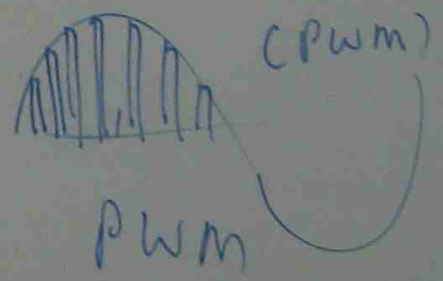


HEATING EFFECT of RIPPLE

RIPPLE → HEATING
→ HARMONIC → NEED TO BE ELIMINATED BY FILTER.
→ VIBRATION

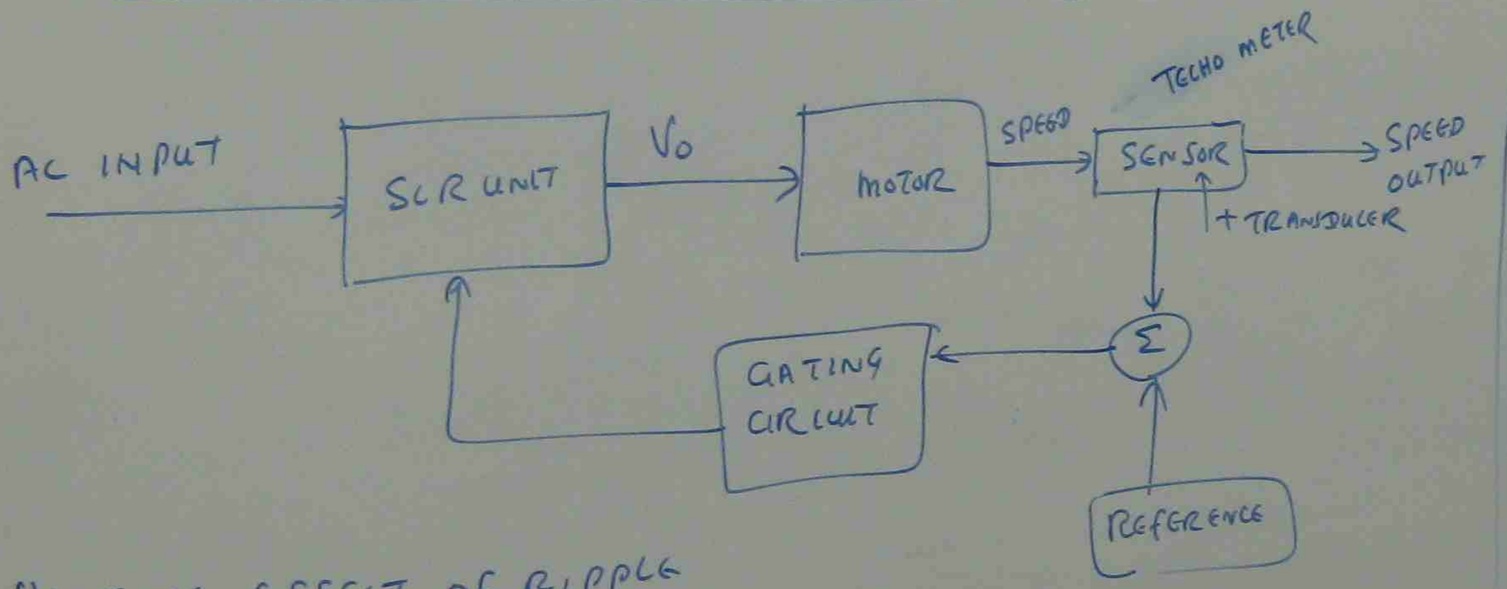
→ DERATE THE MACHING
→ DERATE THE INSULATION

PULSE WIDTH MODULATION (PWM)

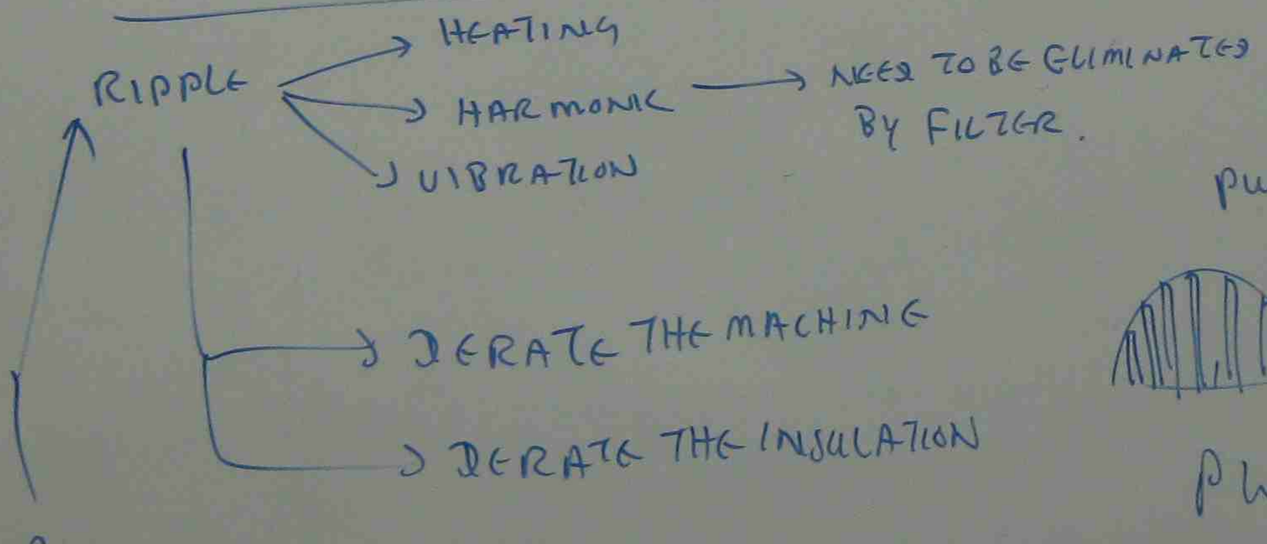


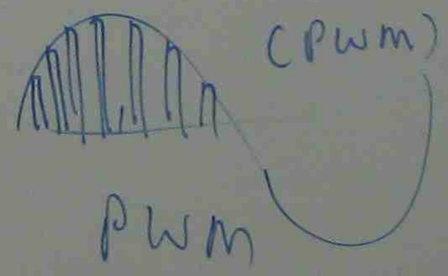
PRODUCED BY
HIGH FREQUENCY SWITCHING CIRCUIT SUCH PWM DRIVES.

BLOCK DIAGRAM of SCR CONTROLLED MOTOR

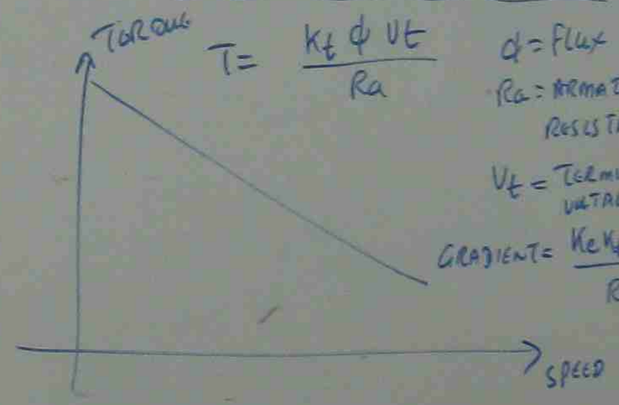


HEATING EFFECT of RIPPLE





TORQUE - SPEED RELATIONSHIP



$$T = \frac{K_t \phi V_t}{R_a}$$

ϕ = Flux

R_a = ARMATURE RESISTANCE

V_t = TERMINAL VOLTAGE

$$\text{GRADIENT} = \frac{K_e K_t \phi^2}{R_a}$$

TORQUE - SPEED CURVE FOR DC SHUNT MOTOR

$$T = K_t \phi I_a$$

T = TORQUE ϕ = FLUX I_a = ARMATURE CURRENT

$$K_t = \frac{pz}{2\pi a}$$

p = NO OF POLE

z = NO. of CONDUCTORS IN ARMATURE

a = ARMATURE PARALLEL PATHS

$$E_g = K_e \phi N$$

N = SPEED

E_g = GENERATED VOLTAGE

$$K_e = \frac{PZ}{60a}$$

$$T = \frac{K_t \phi V_t}{R_a} - \frac{K_e K_t \phi^2 N}{R_a}$$

AC



Pb (REVISION (2)) (EX 9-1)

A 4 POLE WAVE WOUND ARMATURE OPERATING IN A FIELD OF FLUX 0.01 WEBERS IN WOUND WITH 360 ARMATURE CONDUCTORS. DETERMINE THE EXPRESSION OF TORQUE AS A FUNCTION OF SPEED

IF $V_t = 250$ V AND $R_a = 0.1\Omega$.

$$T = \frac{K_t \phi V_t}{R_a} - \frac{K_e K_t \phi^2 N}{R_a}$$

$$K_t = \frac{PZ}{2\pi a} = \frac{4 \times 360}{2 \times 3.1416 \times 2}$$

$$= 114.5$$

$$K_e = \frac{PZ}{60a} = \frac{4 \times 360}{60 \times 2}$$

$$= 12$$

$$T = \frac{114.5 \times 0.01 \times 250}{0.1} - \frac{12 \times 114.5 \times (0.01)^2 \times N}{0.1}$$

$$T = 2860 - 1.38N$$

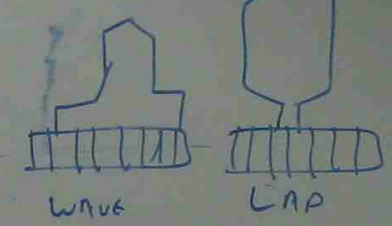
NO LOAD SPEED

$$0 = 2860 - 1.38N$$

$$N = \frac{2860}{1.38} = 2070 \text{ rpm}$$

$a = 2m$ FOR WAVE

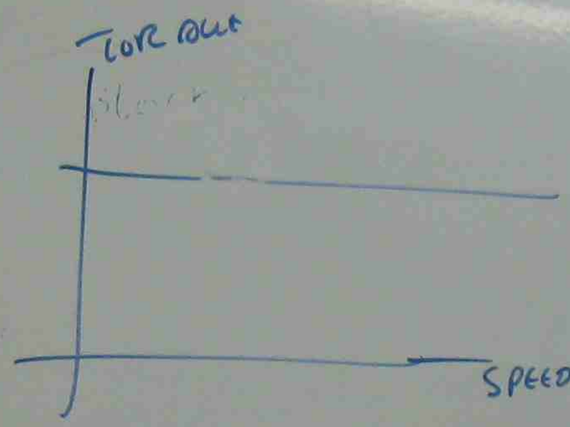
$a = P \times m$ LAP



SIMPLEX $m = 1$

DUPLEX $m = 2$

$a = 2 \times m = 2 \times 1 = 2$



CONSTANT TORQUE CHARACTERISTICS



$T \propto N^2$

MATCH MOTOR & DRIVE SYSTEM

REVISION 2-4

Ex 9.4 FOR MOTOR $T = 2860 - 1.38N$

FOR LOAD (i) $T = 50 + 1.25N$

(ii) $T = 50 + 0.625 \times 10^{-4} N^2$

TO MATCH THE MOTOR AND LOAD, CALCULATE THE EQUILIBRIUM SPEED IN EACH INSTANCE

MOTOR & LOAD $T = 50 + 1.25N$ MATCHING

MOTOR TORQUE = LOAD TORQUE

$2860 - 1.38N = 50 + 1.25N$

$2860 - 50 = 1.38N + 1.25N$

$1.505N = 2810 \longrightarrow N = 1900 rpm$

MOTOR & LOAD $T = 50 + 0.625 \times 10^{-4} N^2$ MATCHING

MOTOR TORQUE = LOAD TORQUE

$2860 - 1.38N = 50 + 0.625 \times 10^{-4} N^2$

$0.625 \times 10^{-4} N^2 + 1.38N - 2860 = 0$

$A X^2 + B X + C = 0$

THE EQUILIBRIUM

$$X = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

$A = 0.625 \times 10^{-4}$, $B = 1.38$, $C = -2860$

$$N = \frac{-1.38 \pm \sqrt{(1.38)^2 - 4 \times 0.625 \times 10^{-4} \times (-2860)}}{2 \times 0.625 \times 10^{-4}}$$

$$= \frac{-1.38 \pm 1.622}{1.25 \times 10^{-4}}$$

$$= \frac{-1.38 + 1.622}{1.25 \times 10^{-4}} = 1930 \text{ rpm}$$

HING

N^2

$$X = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

$A = 0.625 \times 10^{-4}$, $B = 1.38$, $C = -2860$

$$= \frac{-1.38 \pm \sqrt{(1.38)^2 - 4 \times 0.625 \times 10^{-4} \times (-2860)}}{2 \times 0.625 \times 10^{-4}}$$

$$= \frac{-1.38 \pm 1.622}{1.25 \times 10^{-4}}$$

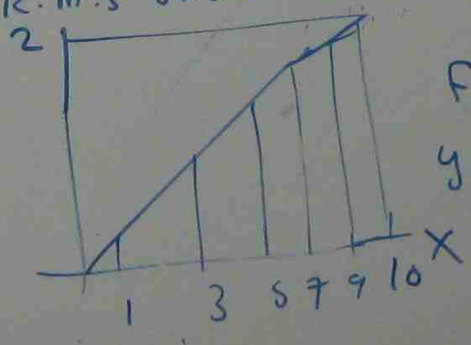
$$= \frac{-1.38 + 1.622}{1.25 \times 10^{-4}} = 1930 \text{ rpm}$$

DUTY CYCLE CALCULATION

AS WELL AS SELECTING A MOTOR THAT IS CAPABLE OF DEVELOPING SUFFICIENT TORQUE TO DRIVE A LOAD AT THE REQUIRED SPEED, THE MOTOR SO CHOSEN MUST BE ABLE TO PROVIDE THIS TORQUE AND NOT SUFFER ANY UNDUE DAMAGE AS A CONSEQUENCE TO THE HEAT PRODUCED WITHIN THE MACHINE BY THE CURRENTS IN THE VARIOUS WINDINGS.

THE HEATING EFFECT IS THE FUNCTION OF THE R.M.S, THE R.M.S VALUE OF THE LOAD MUST BE OBTAINED.

Pb



FIND R.MS

$y = 0.2x$

$$Rms = \sqrt{\frac{1}{y}\int_0^y y^2 dx}$$

$y = 0.2x$

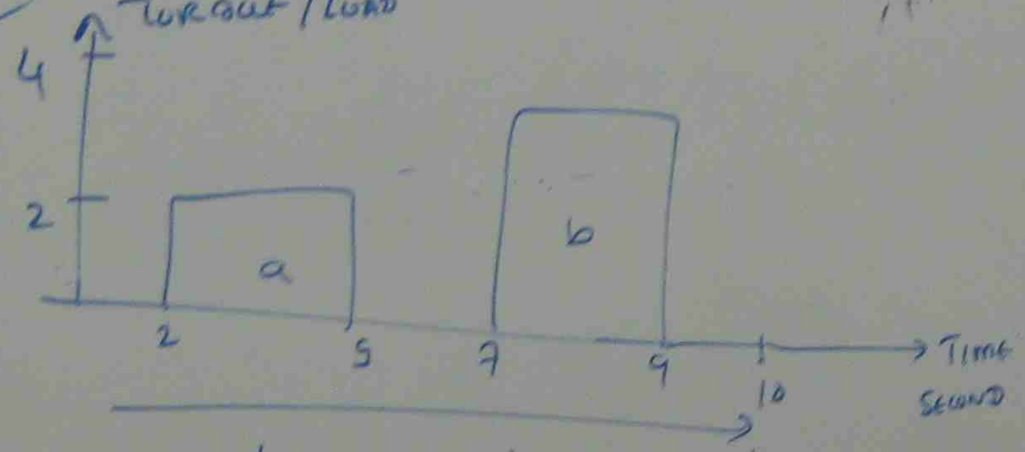
$$Rms = \sqrt{\frac{1}{10}\int_0^{10} (0.2x)^2 dx}$$

$$Rms = \sqrt{\frac{1}{10}\int_0^{10} [0.04x^2 dx]}$$

$$= \sqrt{\frac{1}{10} \times 0.04 \times \left[\frac{x^3}{3}\right]_0^{10}}$$

$$= \sqrt{\frac{1}{10} \times 0.04 \times \frac{10^3}{3}} = 1.152$$

pb FIND Rms OF THE FOLLOWING GRAPH



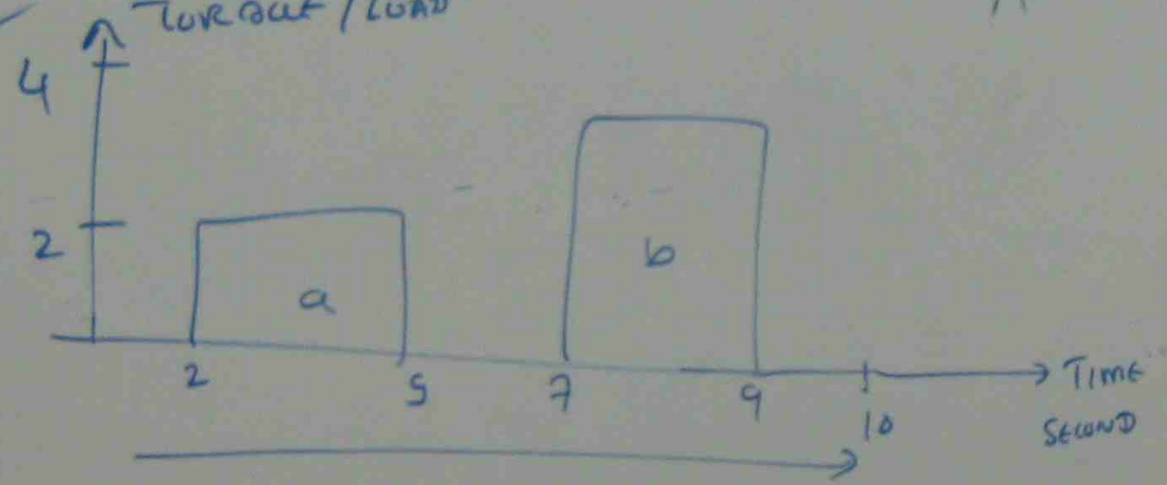
SECTION	DURATION	VALUE	AREA
a	2 → 5 (5-2=3) 3 seconds	2	DURATION X VALUE 3x2=6
b	7 → 9 (9-7=2) 2 sec	4	4x2= 8
		TOTAL	14

$$\text{AVERAGE} = \frac{\text{TOTAL AREA}}{\text{TOTAL DURATION}} = \frac{14}{10} = 1.4$$

$$\text{Rms} = \sqrt{1.4}$$

$$= 1.183$$

Pb FIND RMS OF THE FOLLOWING GRAPH



SECTION	DURATION	VALUE	AREA
a	2 → 5 (5-2 = 3) 3 seconds	2	DURATION X VALUE 3×2=6
b	7 → 9 (9-7=2) 2 sec	4	4×2= 8
		TOTAL	14

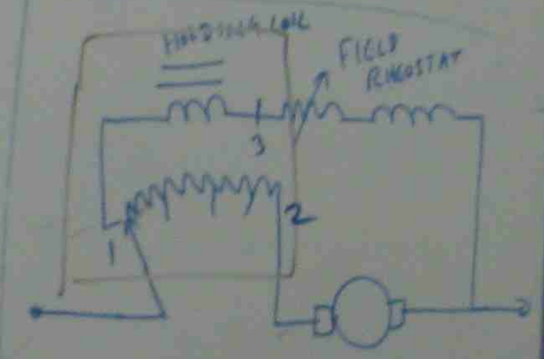
$$\text{AVERAGE} = \frac{\text{TOTAL AREA}}{\text{TOTAL DURATION}}$$

$$= \frac{14}{10} = 1.4$$

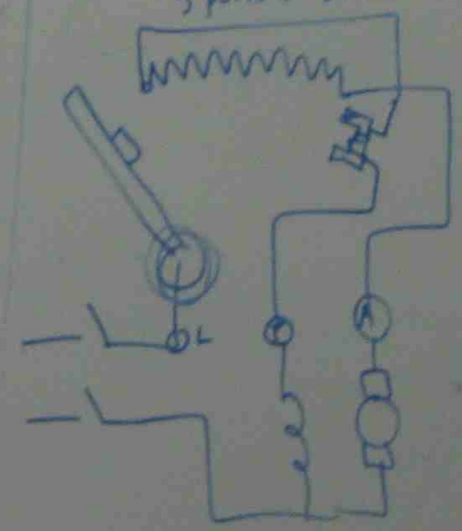
$$\text{RMS} = \sqrt{1.4}$$

$$= 1.183$$

MANUAL STARTERS FOR DC MOTORS



3 POINT STARTER



$$\left(\frac{I_{rmax}}{I_{rmin}}\right)^{n+1} = \frac{V_t}{I_r R_a}$$

n = NO. OF STEPS R_a = ARMATURE RESISTANCE

V_t = TERMINAL VOLTAGE

I_r = FULL LOAD CURRENT

$$\frac{I_s}{I_r} = \frac{R_K}{R_{K+1}}$$

REDUCE THE RESISTANCE OF STARTER AS MOTOR ACCELERATES.

REVISION 2.5

Ex 10.8 THE RESISTANCE OF THE ARMATURE OF A 240V DC SHUNT MOTOR IS 0.5Ω. IT IS REQUIRED THAT THE CURRENT AT STARTING BE LIMITED TO 200% OF FULL LOAD CURRENT AND FULL LOAD CURRENT IS 15 AMPERES.

DETERMINE (a) TOTAL RESISTANCE OF THE ARMATURE CIRCUIT AT STARTING

(b) THE NUMBER OF STUDS ON THE STARTER

(c) THE RESISTANCE BETWEEN EACH STUD.

$R_a = 0.5V$, $V_t = 240V$

$I_r = 15$ Amp (FULL LOAD CURRENT)

$I_s = 200\%\ I_r = 2 \times 15 = 30$ Amp

$$\left(\frac{I_{rmax}}{I_{rmin}}\right)^{n+1} = \frac{V_t}{I_r R_a}$$

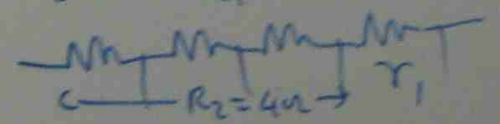
$$\left(\frac{30}{15}\right)^{n+1} = \frac{240}{15 \times 0.5}$$

$$2^{n+1} = 32$$

$$(n+1)\log 2 = \log 32$$

$$n+1 = \frac{\log 32}{\log 2}$$

$$n = \frac{\log 32}{\log 2} - 1 = 4$$



$$\frac{I_s}{I_r} = \frac{R_n}{R_{n+1}}$$

$$\frac{30}{15} = \frac{R_n}{R_{n+1}}$$

$$2 = \frac{R_n}{R_{n+1}}$$

$$R_1 = \frac{V_t}{I_s} = \frac{240}{30} = 8\Omega$$

$$2 = \frac{R_n}{R_{n+1}} \quad n=1$$

$$2 = \frac{R_1}{R_{1+1}} = \frac{R_1}{R_2}$$

$$2 = \frac{8}{R_2} \rightarrow R_2 = 4\Omega$$

$$r_1 = R_1 - R_2 = 8 - 4 = 4\Omega$$

$$2 = \frac{R_n}{R_{n+1}}$$

$n = 2$

$$2 = \frac{R_2}{R_{2+1}}$$

$$2 = \frac{R_2}{R_3}$$

$$2 = \frac{4}{R_3}$$

$$R_3 = \frac{4}{2} = 2\Omega$$

$$r_2 = R_2 - R_3 = 4 - 2 = 2\Omega$$

$n = 3$

$$2 = \frac{R_3}{R_4}$$

$$R_4 = \frac{R_3}{2} = \frac{2}{2} = 1\Omega$$

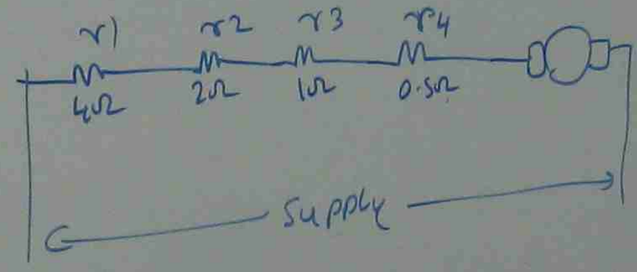
$$r_3 = R_3 - R_4 = 2 - 1 = 1\Omega$$

$n = 4$

$$2 = \frac{R_4}{R_5}$$

$$R_5 = \frac{R_4}{2} = \frac{1}{2} = 0.5\Omega$$

$$r_4 = R_4 - R_5$$
$$= 1 - 0.5 = 0.5\Omega$$



$$2 = \frac{R_n}{R_{n+1}}$$

$n = 2$

$$2 = \frac{R_2}{R_{2+1}}$$

$$2 = \frac{R_2}{R_3}$$

$$2 = \frac{4}{R_3}$$

$$R_3 = \frac{4}{2} = 2\Omega$$

$$r_2 = R_2 - R_3 = 4 - 2 = 2\Omega$$

$n = 3$

$$2 = \frac{R_3}{R_4}$$

$$R_4 = \frac{R_3}{2} = \frac{2}{2} = 1\Omega$$

$$r_3 = R_3 - R_4 = 2 - 1 = 1\Omega.$$

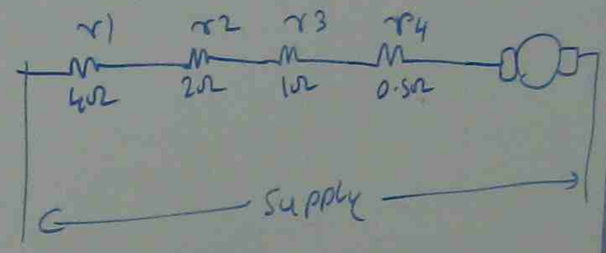
$n = 4$

$$2 = \frac{R_4}{R_5}$$

$$R_5 = \frac{R_4}{2} = \frac{1}{2} = 0.5\Omega$$

$$r_4 = R_4 - R_5$$

$$= 1 - 0.5 = 0.5\Omega$$



$$2 = \frac{R_n}{R_{n+1}}$$

$n = 2$

$$2 = \frac{R_2}{R_{2+1}}$$

$$2 = \frac{R_2}{R_3}$$

$$2 = \frac{4}{R_3}$$

$$R_3 = \frac{4}{2} = 2\Omega$$

$$r_2 = R_2 - R_3 = 4 - 2 = 2\Omega$$

$n = 3$

$$2 = \frac{R_3}{R_4}$$

$$R_4 = \frac{R_3}{2} = \frac{2}{2} = 1\Omega$$

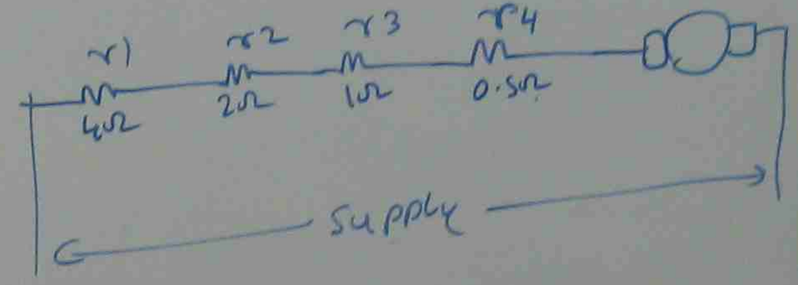
$$r_3 = R_3 - R_4 = 2 - 1 = 1\Omega$$

$n = 4$

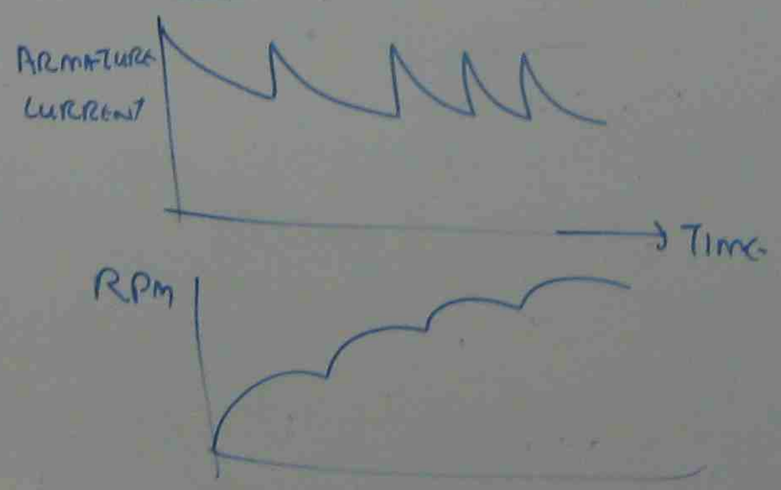
$$2 = \frac{R_4}{R_5}$$

$$R_5 = \frac{R_4}{2} = \frac{1}{2} = 0.5\Omega$$

$$r_4 = R_4 - R_5$$
$$= 1 - 0.5 = 0.5\Omega$$



ACCELERATION OF DC MOTORS



STARTERS

BACK EMF STARTER

CURRENT DEPENDENT STARTER

TIME

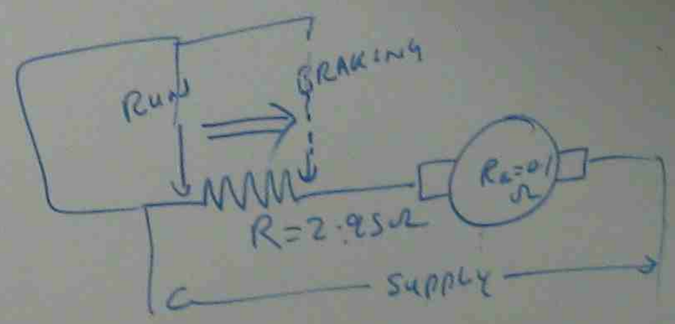
REGULSION

R 2-6

E+11-2

A 240V MOTOR IS REQUIRED TO BE BRAKED BY PLUGGING

IF THE ARMATURE CURRENT AT FULL LOAD IS 100 AMP AND THE ARMATURE RESISTANCE IS 0.1 Ω. CALCULATE THE RESISTANCE OF BRAKING RESISTOR IF THE INITIAL BRAKING CURRENT IS LIMITED TO 150% OF THE FULL LOAD CURRENT AND BRUSH DROP IS TAKEN TO BE 5 VOLTS.



BACK EMF

BRUSH DROP

$$E_b = V_t - (I_a R_a + V_b)$$

$$= 240 - (100 \times 0.1 + 5)$$

$$= 225\ V$$

TIME LIMIT STARTERS

$$I_{br} = \frac{150\%}{100} \times 100 = 150\ Amp$$

$$R_{PLUGGING} = \frac{V_t - (V_b + E_b)}{I_{br}}$$

$$= \frac{240 - (5 + 225)}{150}$$

$$= 3.05\ \Omega$$

ADDED RESISTANCE (ADDITIONAL PLUGGING RESISTOR) = 3.05 - 0.1

= 2.95Ω

REVISION 2/6

Ex 11.2

A 240V MOTOR IS REQUIRED TO BE BRAKED BY PLUGGING. IF THE ARMATURE CURRENT AT FULL LOAD IS 100 AMP AND THE ARMATURE RESISTANCE IS 0.1Ω, CALCULATE THE RESISTANCE THE BRAKING RESISTOR IF THE INITIAL BRAKING CURRENT IS TO BE LIMITED TO 150% OF FULL LOAD CURRENT AND THE BRUSH DROP IS TAKEN TO BE 5 VOLT.

$$R = \text{ARMATURE RESISTANCE} + \text{BRAKING RESISTOR RESISTANCE} = \frac{V_t - V_b + E_g}{I_{br}}$$

$V_t = 240V$, V_b = BRUSH DROP = 5V, E_g = ?

$$E_g = V_t - V_b - I_a R_a = 240 - 5 - 100 \times 0.1 = 225V$$

$$I_{br} = 1.5 \times 100 = 150A$$

$$R = \frac{240 - 5 + 225}{150}$$

$$= 3.05\Omega$$

$$R_a + R_{\text{BREAKING RESISTOR}} = 3.05$$

$$0.1 + R_{\text{BREAKING RESISTOR}} = 3.05$$

$$R_{\text{BREAKING RESISTOR}} = 3.05 - 0.1 = 2.95\Omega$$

LOSSES & EFFICIENCY IN DC MACHINE

ROTATIONAL LOSSES

- HEAT PRODUCED BY BEARING
- HEAT PRODUCED BY ARMATURE CONDUCTORS

BEARING FRICTION, WIND FRICTION, BRUSH FRICTION, HYSTERESIS LOSS, EDDY CURRENT LOSS

- DEPENDS ON MAGNETIC IRON
- FREQUENCY OF SUPPLY
- FLUX DENSITY
- MASS OF IRON

HYSTERESIS LOSS $(P_h) = K_h f B^{1.6} m$ WATT

K_h = CONSTANT DEPENDING ON MATERIALS & UNIT USED

f = FREQUENCY = $\frac{P \times N}{120}$, B = MAXIMUM FLUX DENSITY

m = MASS OF CORE

EDDY CURRENT LOSS

$$P_e = K_e f^2 t^2 B^2 V \quad \text{WATT}$$

K_e = CONSTANT DEPENDING ON RESISTIVITY OF IRON & DIMENSIONS EMPLOYED FOR THE FACTORS

f = FREQUENCY (HZ)

t = THICKNESS OF LAMINATION

B = MAXIMUM FLUX DENSITY IN CORE

V = VOLUME OF IRON CORE.

LOSSES & EFFICIENCY IN DC MACHINE

ROTATIONAL LOSSES

- HEAT PRODUCED BY BEARING
- HEAT PRODUCED BY ARMATURE CONDUCTORS

BEARING FRICTION, WIND FRICTION, BRUSH FRICTION, HYSTERESIS LOSS, EDDY CURRENT LOSS

- DEPENDS ON MAGNETIC IRON
- FREQUENCY OF SUPPLY
- FLUX DENSITY
- MASS OF IRON

Hysteresis loss $(P_h) = K_h f B^{1.6} m$ WATT

K_h = CONSTANT DEPENDING ON MATERIALS & UNIT USED

f = FREQUENCY = $\frac{P \times N}{120}$, B = MAXIMUM FLUX DENSITY

m = MASS OF CORE

EDDY CURRENT LOSS

$P_e = K_e f^2 t^2 B^2 V$ WATT

K_e = CONSTANT DEPENDING ON RESISTIVITY OF IRON & DIMENSIONS EMPLOYED FOR THE FACTORS

f = FREQUENCY (HZ)

t = THICKNESS OF LAMINATION

B = MAXIMUM FLUX DENSITY IN CORE

V = VOLUME OF IRON CORE

COPPER LOSS

- ARMATURE COPPER LOSS $I_a^2 R_a$
- FIELD COPPER LOSS $I_{Sh}^2 R_{Sh}$, $I_{Se}^2 R_{Se}$
- BRUSH COPPER LOSS

STRAY LOAD LOSSES

- WINDAGE LOSS
- FRICTIONAL LOSS

EFFICIENCY OF DC MACHINE

$$\text{EFFICIENCY} = \frac{\text{USEFUL OUTPUT}}{\text{TOTAL INPUT}} \times 100$$

$$P_{OUT} = E_g I_a - W$$

$$P_{IN} = V I$$

$$P_{Loss} = I_a^2 R_a + I_f V_t + W$$

REVISION 2-7

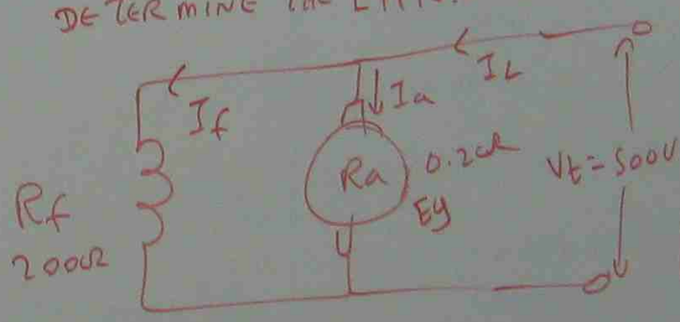
Ex 13.1 THE WINDING RESISTANCES OF A 500V, 60KW DC SHUNT MOTOR ARE

$R_a = 0.2\,\Omega$, $R_f = 200\,\Omega$.

IF THE ROTATIONAL LOSSES CAN BE TAKEN AS 1.4KW, DETERMINE THE EFFICIENCY OF THE MACHINE

(a) WHEN THE LINE CURRENT IS 102.5 AMP

(b) AT FULL LOAD



$$I_f = \frac{V}{R_f} = \frac{500}{200} = 2.5\ A$$

SHUNT FIELD COPPER LOSS $= V \times I_f = 500 \times 2.5 = 1250\,W$

$$I_a = I_L - I_f = 102.5 - 2.5 = 100\ A$$

ARMATURE COPPER LOSS $= I_a^2 R_a = 100^2 \times 0.2$

$= 2000\,W$

TOTAL LOSS = ARMATURE COPPER LOSS + FIELD COPPER LOSS + ROTATIONAL LOSS (W)

= 2000 + 1250 + 1400

= 4650 WATT

OUT PUT POWER = INPUT − TOTAL LOSSES

= VI − 4650

= 500 × 102.5 − 4650

EFFICIENCY = $\frac{\text{OUT PUT}}{\text{INPUT}} \times 100$

= $\frac{500 \times 102.5 - 4650}{500 \times 102.5} \times 100$

= 90.93 %.

Full load

P_{out} = 60,000 WATT

$P_{out} = E_g I_a - W$ ← ROTATIONAL LOSS

$60{,}000 = E_g I_a - 1400$

$E_g I_a = 60{,}000 + 1400 = 61400$ WATT

$E_g = V_t - I_a R_a =$

$(V_t - I_a R_a) I_a = 61400$

$(500 - I_a \times 0.2) I_a = 61400$

$I_a^2 - 2500 I_a + 30700 = 0$

$A x^2 + B x + C = 0$

$x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$

$= \frac{-(-2500) \pm \sqrt{(-2500)^2 - 4 \times 1 \times 30700}}{2 \times 1}$

$= \frac{259}{2}$ (OR) $\frac{4741}{2}$

$I_a = \frac{254}{2} = 129.5$ Amp.

ARMATURE loss = $I_a^2 R_a$

$= 129.5^2 \times 0.1$

= 3352 w

FIELD loss = 1250 w

$I = I_a + I_f$

= 129.5 + 2.5

= 132

$P_{IN} = 132 \times 500$

= 66000 W

$\eta = \frac{P_o}{P_{IN}} \times 100$

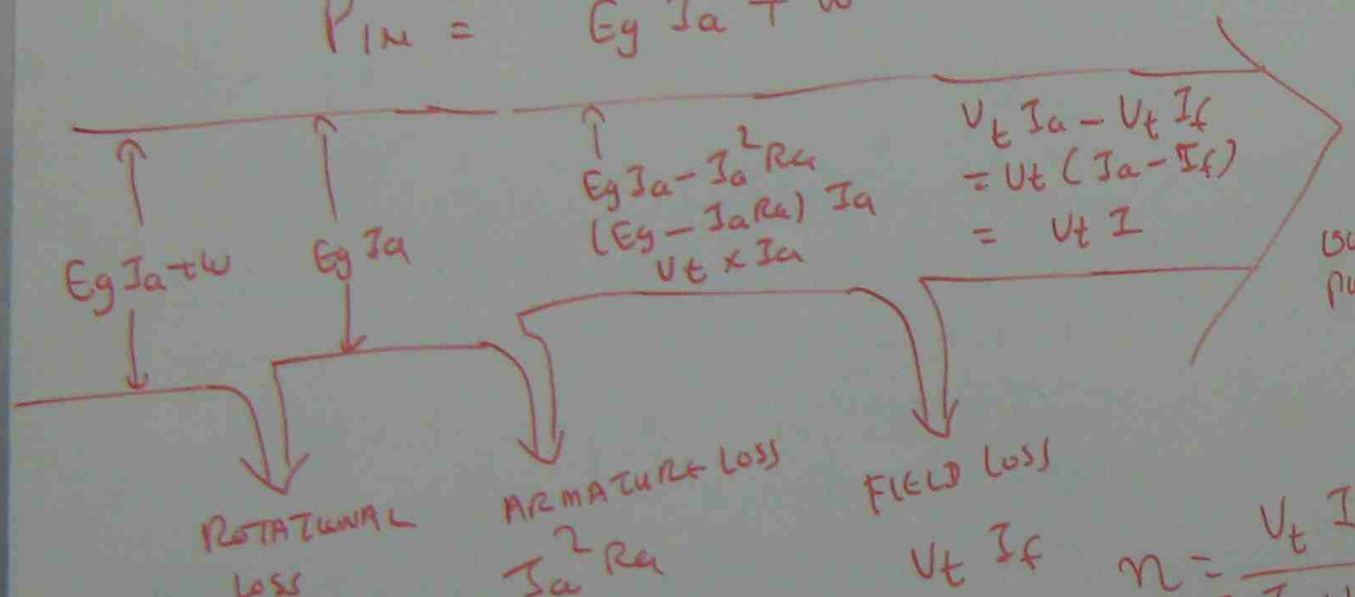
$= \frac{60{,}000}{66000} \times 100$

= 90.9 %.

DC GENERATORS

$$P_{OUT} = V_t \times I$$

$$P_{IN} = E_g I_a + W \leftarrow \text{ROTATIONAL LOSSES}$$



$$\eta = \frac{V_t I}{E_g I_a + W} \times 100$$

POWER FLOW DIAGRAM IN DC GENERATOR

R2-3
E+13.2

THE LOSSES IN A 250 KW GENERATOR ARE 19.5 KW. CALCULATE THE EFFICIENCY OF THE MACHINE

$$\eta\% = \left(1 - \frac{P_{loss}}{P_{OUT} + P_{loss}}\right) \times 100$$

$$= \left(1 - \frac{19.5}{250 + 19.5}\right) \times 100$$

$$= 92.79\%$$

MAXIMUM EFFICIENCY

$$\eta_{MAX} = \frac{P_{OUT}}{P_{OUT} + 2I_a^2 R_a} \times 100$$

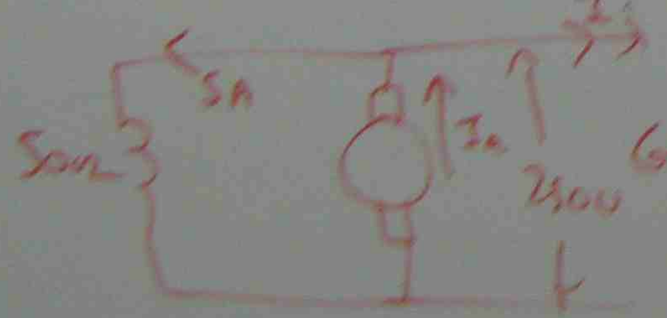
R2.9

A 60 KW, 250V SHUNT GENERATOR HAS AN ARMATURE CIRCUIT RESISTANCE OF 0.05Ω. FIELD RESISTANCE OF 50Ω AND A MAXIMUM EFFICIENCY 91%. CALCULATE

(a) THE TOTAL LOAD FOR WHICH THE EFFICIENCY IS APPROXIMATELY A MAXIMUM

(b) THE STRAY POWER LOSS

$$\%\eta = \frac{250\,I}{250\,I + 2\,I_a^2\,R_a} \times 100$$



$I_a = I + I_f$
$= I + 5$

$$91 = \frac{250\,I}{250\,I + 2\,(I+5)^2 \times 0.05} \times 100$$

$I = 247.2$ AMP

STRAY LOSS: $I_a^2 R_a - VI_f$

$= (249.2)^2 \times 0.05 - 250 \times 5$

$= (252.2)^2 \times 0.05 - 1250$

$= 1200$ W //

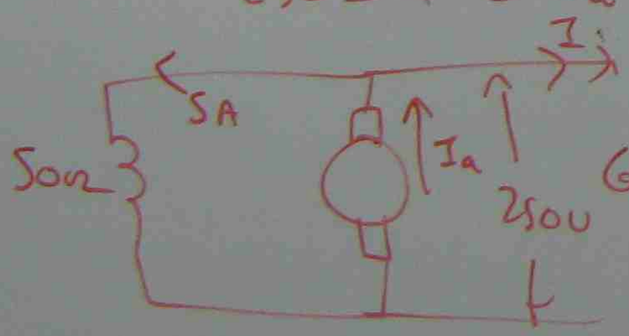
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$I_a = I + I_f$

$= I + 5$

$$91 = \frac{250\,I}{250I + 2(I+5)^2 \times 0.05} \times 100$$

$I = 247.2$ Amp

STRAY loss: $I_a^2 R_a - V_t I_f$

$= (247.2+5)^2 \times 0.05 - 250 \times 5$

$= (252.2)^2 \times 0.05 - 1250$

$= 1800$ W //

KAPP TEST ⟶ MAXIMUM EFFICIENCY TEST
ON PAGE 125 of TEXT BOOK

MACHINE TEMPERATURE RISE

(a) THERMO METER
(b) EMBEDDED THERMO COUPLE (OR) THERMISTOR
(c) COMPUTATION FROM HOT & COLD RESISTANCE

$$\frac{R_f}{R_{RT}} = \frac{234.5 + T_f}{234.5 + T_{RT}}$$

R_{2-10}

THE RESISTANCE OF AN ARMATURE WINDING AT 25°C WAS FOUND TO BE 0.26Ω AFTER A HEAT RUN, IT BECOMES 0.296Ω. CALCULATE TEMPERATURE RISE OF THE WINDING.

$R_{RT} = 0.26\Omega$

$R_F = 0.296\Omega$

$T_{RT} = 25°C$

$T_F = ?$

$$\frac{R_f}{R_{RT}} = \frac{234.5 + T_f}{234.5 + T_{RT}}$$

$$\frac{0.296}{0.26} = \frac{234.5 + T_f}{234.5 + 25}$$

$$\frac{0.296}{0.26}(234.5 + 25) - 234.5 = T_f$$

$T_F = 61°C$

TEMPERATURE RISE $= T_F - T_{RT} = 61 - 25 = 36°C$

KAPP TEST ⟶ MAXIMUM EFFICIENCY TEST
ON PAGE 125 of TEXT BOOK

MACHINE TEMPERATURE RISE

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$$\frac{R_F}{R_{RT}} = \frac{234.5 + T_f}{234.5 + T_{RT}}$$

R2-10 THE RESISTANCE OF AN ARMATURE WINDING AT 25°C WAS FOUND TO BE 0.26Ω AFTER A HEAT RUN, IT BECOMES 0.296Ω. CALCULATE TEMPERATURE RISE OF THE WINDING.

$R_{RT} = 0.26\Omega$

$R_F = 0.296\Omega$

$T_{RT} = 25^\circ C$

$T_F = ?$

$$\frac{R_F}{R_{RT}} = \frac{234.5 + T_f}{234.5 + T_{RT}}$$

$$\frac{0.296}{0.26} = \frac{234.5 + T_f}{234.5 + 25}$$

$$\frac{0.296}{0.26}(234.5 + 25) - 234.5 = T_f$$

$T_F = 61^\circ C$

TEMPERATURE RISE $= T_F - T_{RT} = 61 - 25 = 36^\circ C$