

Sl. No.	Application	Machine.
1.	Welding Generator Set.	Differential Compound Generator
2.	Clock Blower	Synchronous Motor, SCIM
3.	Tape Recorder.	Hysteresis Motor.
4.	Increase & decrease the line voltage to get the required o/p voltage	Buck-boost T/f, in AC voltage stabilizer.
5.	Welding for rail end or rolled section.	Flash Butt welding.
6.	Sewing machine	Universal Motor.
7.	Servo line voltage correction	Auto Transformer.
8.	Measure the voltage of lead acid cell	High Rate Discharge Tester.
9.	Const. speed at varying load	Synchronous Motor.
10.	Compound Motor with speed control above normal.	4-point starter.
11.	Chodown lighting 5 no. of lamps	1-SPT, 4 2-way switch
12.	On load tap changer	Rotary Converter.
13.	Semi-Automatic Y- Δ started	Power T/f, 3-Contactor.
14.	Detect and locate grounded shorted and open coils in an armature.	External breather
15.	Coupling gap reading	Feeler Gauge
16.	Single M/c can generate AC or DC as well as AC & DC both	Rotary Converter
17.	5 way switch connection	3-Intermediate switch 2-Two-way
18.	Auto Transformer	Servo line voltage correction.
19.	Pf. improvement at S.V. Lamp	Capacitor.
20.	Const. speed at varying load	Synchr Motor
21.	To move heavy equipment	Winches, Crane & Slings
22.	PTC Resistor	Semistor

TEST OF ELECTRICAL MACHINE,

S1. No.	Name of Test	Machine	Result	Comments
01.	Swinburne's Test.	DC M/C Const. flux & Indirectly $\eta = \frac{V - I_a}{V}$	Constant Loss.	No load Test. Not for Series M/C Const. Flux M/C
02.	Absolute method, Deflection w/ Null	Instrument T/f.		
03.	Shunt field Opened.	DC Compound Motor	Motor Get Heated.	
04.	Continuous Chattering sound from armature of A.C. N.V. coil		Open ckt in shading Ring.	
05.	Short ckt test on coil test on medium size m/c.	Generator.		
06.	Speed control of Ceiling Fan	Rheostatic Electromic	Almost same power com. More Power $\rightarrow$ More Speed Less Power $\rightarrow$ Less Speed	
07.	Hopkinson Test.	Two identical DC M/C Shunt	Motor η Gen η	Regenerative Test/Block to back test.
08.	Blowier's Test		Ground fault of Single cable	
09.	Field Test	DC M/C Series	To test two similar DC series motor	Motor η Gen η
10.	Retardation/Run Down Test.	DC M/C	Stray Loss.	
11.	Brake Test	DC M/C	Efficiency	
12.	Murray loop Test Kelley loop Test		Fault location of U/L cable	

TRANSFORMER

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1. Wgt of Cu in auto t/f = $(1-k) \times \text{Wgt. of Cu in ord. T/f.}$

$$W_a = (1-k) W_o \quad (k < 1)$$

2. Power transferred inductively from P to S in an auto t/f. ~~conductively~~

$$P_i = (1-k) \times \text{Load}$$

If $k=0.5$ then $\frac{P_i}{P_o} = \frac{1}{2}$ i.e. 50% power is transferred inductively & 50% conductively.

3. Maximum Efficiency:-

D/n T/f. $\rightarrow$ Lower value of Full load (50% F.L)

Power T/f. $\rightarrow$ At full load.

4. Auto t/f. $\rightarrow$ Self Induction.
T/f. $\rightarrow$ Mut. η

5. Tapping provided on H.V. side. (2 t/f. centre tapped)

6. Teaser T/f tapping in Scott connection $\rightarrow$ 86.6%

7. EMF per turn of transformer $\rightarrow 4.44 f \Phi_m$

8. All day η / Commercial η / Ordinary η

$$= \frac{\text{O/P in watt}}{\text{I/P in watt}} \quad \frac{\text{O/P in kWh}}{\text{I/P in kWh}} \quad \text{Operational } \eta$$

9. Interleaved disc connection used for H.V. T/f.

10. Utilization factor for t/f. in open delta

$$\rightarrow 0.577$$

$$\frac{\text{V-V Capacity}}{\Delta-\Delta \text{ Capacity}} = \frac{\sqrt{3} V_s I_s}{3 V_s I_s} = \frac{1}{\sqrt{3}} = 0.577 \text{ or } 57.7\%$$

11. Rating in kVA $\rightarrow$ kW varies as pf. varies

12. Limitation of Auto T/f $\rightarrow$ May get shock from L.V. side

13. Main earthing of D/n. T/f. $\rightarrow$ Neutral Earthing.
14. H.V. side $\rightarrow$ Air Brake Sw. $\rightarrow$ T/f.
15. Scott Connection $\rightarrow$ 3 ϕ to 2 ϕ
16. C.B.C.T $\rightarrow$ Core Balanced Current T/f.
17. Indoor T/f. rating above. 630kVA.

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Cooling of Transformer:-

	Methods	Rating.
1.	Air Natural (AN)	upto 1.5 MVA
2.	Air Blast (AB)	upto 15 MVA
3.	Oil Natural Air (ONAN) Nat.	Upto 30 MVA.
4.	Oil Natural-Air forced (ONAF)	30 MVA , upto 60 MVA
5.	Oil forced-Air Natural (OFAN)	30 MVA.
6.	Oil forced-Air forced (OFAF)	
7.	Oil Nat. - Water forced (ONWF)	Power Plant
8.	Oil forced - Water forced (OFWF)	Power Plant.

~~Flux~~ Flux Density $\uparrow \rightarrow \downarrow$ Wgt/kVA.

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No. load primary current = 1% of f.l. current.

(*) Frequency $\uparrow \Rightarrow$ Size $\downarrow$

(*) ONAF $\rightarrow$ 10 MVA

(*) Cylindrical winding used beyond $\Rightarrow$ 6 KV

(*) Air Core T/f. $\rightarrow$ NO magnetic core loss.

(*) Sec. Line voltage maximum for Δ -Y

$I_N = I_0 \cos \phi_0$	Core loss Component Watt less "
$I_M = I_0 \sin \phi_0$	

(*) Power T/f is const. main flux device.

(*) In Δ -Y T/f. ~~pp~~ phase diff. between primary & sec.
 $\rightarrow 30^\circ$

(*) Crackle Test $\rightarrow$ T/f oil $\rightarrow$ Water content.

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SYNCHRONOUS MOTOR

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Torque Angle $\rightarrow$ Rotating Stator flux & Rotor Poles.

Requires AC & DC Both.

Back emf on a Synch. Motor Rotor ~~also~~ depends on Rotor excitation only.

Alternator Regulation at ~~unity~~ p.f. $\Rightarrow$ +ve

lagging $\Rightarrow$ +ve, 0

leading $\Rightarrow$ -ve.

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V curve

Inverted V curve

x axis	y axis
DC Field Current	Arm current / A
DC Field Current	Power Factor,

Excitation removed 2nd Reluctance Motor 2nd Run 2nd

$$P_m = \frac{E_b V}{X_d} \sin \alpha + \frac{V^2}{2} \frac{X_d - X_q}{X_d X_q} \sin 2\alpha$$

Mech. Power Developed

Excitation

Reluctance

ElectricalNoteBook.com Power.

1. Condition for max^m torque on IM →

$$R_2 = SX_2$$

2. Rotor Cu loss = $(S \times \text{Rotor i/p}) = \left(\frac{S}{1-S}\right) \times \text{Mech. Power of P.}$

3. To give protection.

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Starter	Starting Current (I_s)	Starting Torque (T_s)	
DOL	$(I_s)_\Delta = \sqrt{3} \cdot I_{sc}$	$(T_s)_\Delta = \left[\frac{(I_s)_\Delta}{I_{fl}}\right]^2 S_{fl} \cdot T_{fl}$	Best starting torque
Impedance	$(I_s)_Z = \kappa \cdot (I_s)_\Delta$	$(T_s)_Z = \kappa^2 \cdot (T_s)_\Delta$	$\kappa < 1$
Auto T/f. (3 terminals)	$(I_s)_{\text{auto}} = \kappa^2 \cdot (I_s)_\Delta$	$(T_s)_{\text{auto}} = \kappa^2 \cdot (T_s)_\Delta$	$\kappa < 1$
Y-Δ (6 Terminals)	$(I_s)_Y = \frac{1}{3} \cdot (I_s)_\Delta$	$(T_s)_Y = \frac{1}{3} \cdot (T_s)_\Delta$ $\uparrow T_\Delta = \kappa \quad T_Y = \frac{\kappa}{3}$	Voltage reduced by $\frac{1}{\sqrt{3}}$ times.

4. Full load → p.f. near about unity, ($T_s = \text{Delta starting}$)

5.
$$P_2 : P_m : I^2 R = 1 : (1-S) : S$$

6. DOL starter → O/L Relay set → Actual Load Current.
 other " → O/L " " → More than actual load Curr

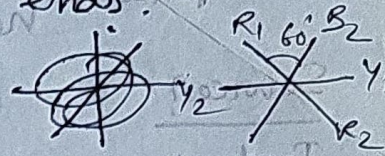
7. Condition for max T_{st}

$$\begin{aligned} T_{\text{max at starting}} & \rightarrow R_2 = X_2 \\ T_{\text{max at running}} & \rightarrow R_2 = SX_2 \end{aligned}$$

8. Starting current (I_{st}) → 5 to 7 times of I_{fl}
 Starting torque (T_{st}) → 1.5 times of T_{fl}

9. Skews done for reducing Slot harmonics.
 Crawling due to Space harmonics.

10. Double Cage IM $\rightarrow$ Inner Cage $\rightarrow R \downarrow \quad X \uparrow$
 Outer Cage $\rightarrow R \uparrow \quad X \downarrow$
11. Synch. Voltage $\rightarrow$ Rotor power input.
12. F.L. Current of S.H.P. motor $\rightarrow 7.5A$.
13. Angle between the dissimilar stator ends of adjacent stator coil $\rightarrow 60^\circ$



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14. Slip Ring I.M. can run with Super Synch. Speed by Stator Scherbius Scheme.
15. It can't run in synch. speed $\rightarrow$ then rotor torque would become zero.

16. Concentrated winding $\rightarrow$ Coil/pole/phase = 1.
17. Speed decrease slightly with increase of load.
18. Low voltage $\rightarrow$ (Current $\uparrow$)
 High Exch $\rightarrow$ $n \rightarrow n \uparrow$
19. High capacity S.C.I.M. is not used under low load condition $\rightarrow$ p.f. will be less.

20. Rotor bars are skew $\rightarrow$
- ① To prevent rotor from aligning & locking up with stator
 - ② To give more uniform torque
 - ③ To reduce humming noise

21. Inching $\rightarrow$ Jogging.

22. Fully automatic Y- Δ starter $\rightarrow$ 3 Contactors.

23. Large Air gap $\rightarrow$ increased O.L. Capacity.

24. No load current = 40% of f.l. current.

25. High Speed motor pf $\Rightarrow$ High
 Low $\Rightarrow$ Low

26. Y- Δ starting is eqv. to auto tf. starting with 57.7% tapping.

27. Synch. Speed of Lin. Induction motor $\boxed{ws = 2wf}$

w = width of one pole pitch

f = supply freq

28. Total Z of ECL = 1Ω

Pitch Factor $(K_p) = \cos \frac{\alpha}{2}$ vector sum Arithmetic ALTERNATOR Dist. factor $(K_d) = \frac{\sin m\beta/2}{m \sin \beta/2}$

1. Maximum Power ofp when $\alpha \leq 90^\circ$ ($\alpha = \text{lead Angle}$)
2. Power formula - $P = \frac{E V \sin \alpha}{X_s}$ (Cylindrical pole)

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3. Maximum Power ofp. of the alternator.

$$P_{max} = \frac{E}{V} \cdot \frac{100}{\% X_s} \times \text{f.L. power ofp. at upf}$$

4. A salient pole synch. m/c has P_{max} output when power angle is $\rightarrow$ Less than 90°

5. Sal. pole synch. m/c if $X_d = X_q$ Power dev. due to reluctance is zero

6. Power dev. at salient pole synch. m/c

$$P = \left[\frac{E V}{X_d} \sin \delta \right] + \left[\frac{V^2}{2} \cdot \frac{(X_d - X_q)}{(X_d \cdot X_q)} \cdot \sin 2\delta \right]$$

Power developed due to excitation

Power dev. due to Reluctance

$\delta = \text{load Angle / Power angle. } E = \text{Ext. voltage}$
 $V = \text{Term. "}$
 $45^\circ \text{ to } 90^\circ$

7.
$$\left. \begin{array}{l} \text{Salient Pole} \rightarrow \delta < 90^\circ \\ \text{Cylindrical Pole} \rightarrow \delta = 90^\circ \end{array} \right\} \text{Condition for Max Power ofp.}$$

8. Power Developed in Cylindrical pole synch. m/c

$$P = \frac{E V \sin \delta}{X_d}$$

$X_d = \text{Direct Axis.}$
 $X_q = \text{Quadrature Axis.}$

9. For Salient Pole m/c $\rightarrow X_d > X_q$
 Cylindrical " m/c $\rightarrow X_d = X_q$

10. Excitation $\uparrow \rightarrow$ Synch. Motor - pf. $\rightarrow$ Leading
 $\uparrow \rightarrow$ Synch. Gen. $\rightarrow$ pf. $\rightarrow$ Lagging

Ⓢ Alternator used to generate definite freq.

Alternator Cooling Methods:-

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Air Cooling (less than 50 MW) → Radial flow & Ventilation
 Hydrogen (50 - 500 MW) → Axial Flow Ventilation
 Water (500 MW or More) → Circumferential

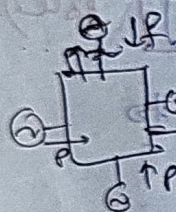
Dist. winding Same length

Hydrogen Cooling ($H_2 : Air = 9 : 1$)

* Fractional Pitch $\Rightarrow \frac{4}{5}$ eliminated 5th harmonics.
 $\Rightarrow \frac{2}{3}$ " " " 3rd harmonic

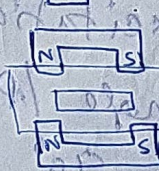
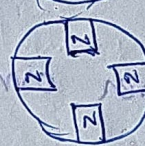
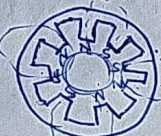
* Harmonics freqⁿ (f_n) = $n \cdot f_1$ f_1 1st harmonic freqⁿ

* Common grid
 Freqⁿ of alternator in zone of common grid is ↓
 then power from grid will flow to that zone.



~~Homopolar m/c~~

~~Heteropolar m/c~~



Heteropolar m/c

Homopolar m/c

* Generate define freqⁿ

* Two alternator sharing inductive load equally
 1. alternator speed ↑ another share less current

Voltage Reg. Methods

EMF method → Bohn Eschenberg Method

MMF method → Potier's Method (Optimistic)

Potier's Triangle → Zero P.F

Synch. Z method → Pessimistic

Shaded Pole Motor:-

- Lowest st. torque
- Photographic instr.

Universal Motor

- Highest Power to weight ratio.
- Speed control at Gen. m/c → Resistor in series.
- Can run as a sync.

Rep Single Phase Motor.

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⊗ Repulsion Motor → Traction (Elect. Train)

1. A Series characteristics motor
2. Maximum torque developed when brush axis is at 45° ~~with~~ electrical ~~as~~ with field axis.
3. Have high pf.
4. Short cuted brush.
5. Speed control by brush shift.

~~Electric clock~~

Hysteresis Motor.

Ceramic permanent magnet.
alnico, alloy

Starting → P.M.

Running → Synch. Motor

⊗ 1. Rotor made → Chrome-steel (ferro-mag material)

2. Run in Synch. speed.

3. No winding on rotor

Two winding main, aux.

No eddy current loss only hyst. loss.

Start → eddy current torque

Run → Hyst. Torque

Schrage Motor.

Start → Shaded pole motor

AC M/A.

⊗ Size upto 300kW. Synch

⊗ Rotor feed 3-φ commutator induction motor.

2 winding → 2 in ~~rotor~~ rotor.

1 in stator.

⊗ Can run 0, +ve, -ve sup.

Primary (lower part)

Regulating (upper)

Sec. winding.

Servo Motor

⊗ 2-Phase Induction Motor.

⊗ Most suitable servomotor for low power app → DC Shunt motor

Reluctance Motor

⊗ Stator poles ≠ Rotor Poles



⊗ 1-φ Synch. Motor.

⊗ Most suitable for high power application.

⊗ const. speed.

I-φ IM

→ starting Cap $\leq \frac{1}{5}$ Running Cap.

Cap. Start Cap. Run → Paper Cap.

from rotor either direct
→ fault → open cap.

Winding → Concentric winding.

Ceiling fan → Cap. Run Ind. Motor.

St. winding of
fridge → Magnetic
Relay.

Start Capacitor → Electrolytic Cap.

High freq. App. → Mica Cap.

DC machine

Polarity of Interpole:-

DC Generator $\rightarrow$ Same as next main pole **ahead** in dir. of R.

DC Motor $\rightarrow$ " " " " **after** " " " " **behind** " " " "

O/p. voltage can be regulated by controlling the generator speed.

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① Intermittent Starting torque $\rightarrow$ Comm. Compound Motor

DC Generator:

1. No. load saturation char (OCC) (E_o/I_f)
2. Internal Char. (Total Char.) (E_o/I_a)
3. External Char. (V/I_L)

Voltage drop at Cu-Carbon brush $\rightarrow 2V$

① ~~Critical~~ Critical Resistance Line just touch the OCC

① Nature of current flowing through arm. of d.c. m/c is A.C.

① No. of Comm. Segment = No. of Armature coil

① Line Commutation is natural commutation.

① Reactance voltage in D.C. m/c depends on Arm. current

① Stray loss = Mag. loss + Mech. loss

① Max voltage between commutator segment $\rightarrow 15V$

① Thickness of laminations $\rightarrow 0.5mm$

① Comm. Comp. DC Motor $\rightarrow$ Load speed $\downarrow$

① Main drawback of D.C. Shunt Gen $\rightarrow$ terminal voltage drops considerably with load.

① Common method of speed control is $\rightarrow$ Rfd control.

① Frog leg winding $\rightarrow$ used to eliminate the use of equalizer in lap winding.

Given, Comm. dia - 50cm, rotating at 1000 rpm, brush width 1.5cm, find time of commutation in ms. ElectricalNotebook.com

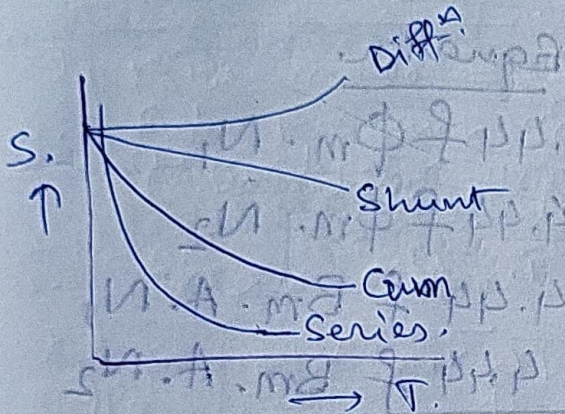
$\Rightarrow$ Circumference = $\pi d = 157.07 \text{ cm}$
 1 sec - distance covered = $\frac{1000}{60} \times 157.07 = 2617.93 \text{ cm}$
 Time of comm = $\frac{1.5}{2617.93} = 0.573 \text{ ms}$

⊕ Reactance Voltage - The self induced emf in coil under going commutation is called Reactance voltage.

⊕ Under compound DC gen. doesn't need equalisers for satisfactory Parallel operation.

DC Motor,

field open Shunt $\rightarrow$ Huge Speed
 " " Series $\rightarrow$ Not run



⊕ No. of brushes depends on amount of current to be collected.

⊕ Electromagnetic torque & speed are in opposite direction in case of Shunt generator.

Armature mmf in DC m/c is

STATIONARY w.r.t. field

⊗ ROTATING w.r.t. armature

Series R with DC series motor $\rightarrow$ Speed $\downarrow$.

⊗	Stray Loss $\propto I_L^2$	(DC m/c)	1% of Rated o/p.
⊗	Stray Loss $\propto I_{\text{Rotor}}^2$	(AC m/c)	0.5% for Ind./Synch. m/c

⊕ Armature reaction in DC motor $\rightarrow$ Increase Speed.

⊗ Electromagnetic Torque = Shaft Torque + Mech. loss.
 ↑
 Arm. Torque.

⊗ Domestic Mixer Grinder $\rightarrow$ Tapped field Control.

⊗ No. of tapping from each Equilizer Ring = No. of pole pair.

⊗ Metal Graphite Brush = 0.5 - 1V Drop
 Carbon or " = 1.5 - 2.5V "

⊗ Maximum ϕ emf at 90° with field axis.

⊗ 4 pt. starter $\rightarrow$ Fld. Control (speed) shunt motor

⊗ $R_{LAP} = \frac{Z}{p^2} \cdot \frac{PL}{A}$

$R_{wave} = \frac{Z}{4} \cdot \frac{PL}{A}$

$Z =$ No. of cond. $p =$ pole

Battery

Sp. Gravity of a fully charged lead-acid battery $\rightarrow 1.28$.

	Fully charged	Fully discharged
+ve plate	Chocolate Brown	Whitish
-ve plate	Slaty Gray	

EMF equation

M/c.

Equation

1. Transformer

$$E_1 = 4.44 f \Phi_m \cdot N_1$$

$$E_2 = 4.44 f \Phi_m \cdot N_2$$

$$E_1 = 4.44 f B_m \cdot A \cdot N_1$$

$$E_2 = 4.44 f B_m \cdot A \cdot N_2$$

2. Alternator

$$E = 4.44 f \Phi T K_p K_d$$

$T \Rightarrow$ Turns/ph. $K_p =$ Pitch factor.

$K_d =$ Dist. Factor ~~$K_p =$ Form~~

Pitch of Wave winding $\Rightarrow Y_B + Y_F$

Pitch of Lap winding $\Rightarrow Y_B - Y_F$



Armature torque

$$T_A = 0.159 \Phi Z I_a \left(\frac{P}{A} \right) \text{ N-m}$$

Power

$$P = \frac{2\pi N T}{60}$$

(N in rpm)

$$\frac{P \Phi Z}{A} I_a$$

Short pitch $\rightarrow$ To reduce amount of copper.

No. of ~~arm.~~ compensating winding conductor $= \frac{Z}{A}$

No. of compensating winding per pole $= \frac{Z'}{AP}$

If Pole Arc/pole pitch is given then

no. of compensating winding per pole $= \frac{Z'}{AP} \times \frac{\text{Pole Arc}}{\text{Pole Pitch}}$

50% pole pitch is enough but we design

generally 70% of pole pitch

Battery

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Commutation → Current reversal within commutating time is called commutation.

n time $\rightarrow 1\text{msec} - 2\text{msec}$.

⇒ Current reverses completely within $T_c \rightarrow$ Successful commutation.

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n doesn't reverse completely within $T_c \rightarrow$ Non-Linear commutation

Sparking at trailing edge of brush.

Delayed

$$T_c = \frac{W_B - W_m}{v}$$

T_c = Comm. Time

W_B = Brush width

W_m = Mica

v = velocity in cm/sec.

$$v = \frac{\pi D N}{60}$$

N = Speed in rpm

D = Dia. of Arm.

Reactance voltage $\rightarrow e_r = L \frac{di}{dt}$

⇒ To ~~Reduce~~ Improve Commutation.

- ① Resistive commutation
- ② Brush Shift (earlier)
- ③ Interpoles. ③ Interpoles.

Interpoles → To reduce arm. magnetisation. (connected with series in through brushes, arm.)

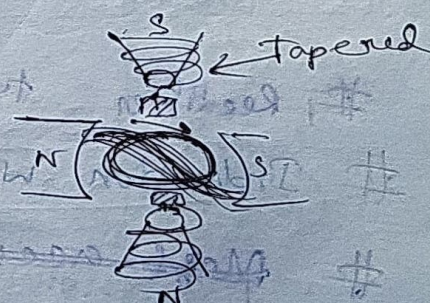


Neutralize Reactance voltage

Remove inequality in flux density on top & bottom half of pole

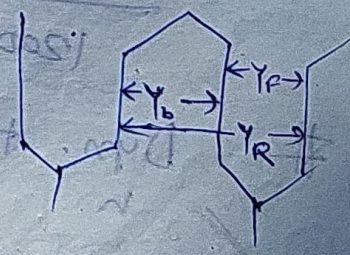
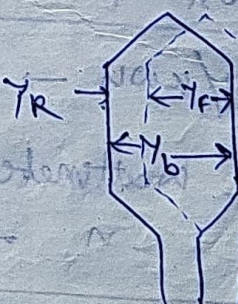
Tapped → ~~imp~~ Saturated or 2x more airgap.

No. of tapping from each eq. Ring = $\frac{\text{No. of pole pair}}{2}$



Lap → Any even no. of cond.

Wave → Even no. that exactly multiplied by 2 of pole + 2



$$Y_R = Y_B + Y_F$$

$$Y_R = Y_B + Y_F$$

$$\text{Dummy Coil} = 2 \pm 2$$

Stepper Motor.

- ① Variable Reluctance
- ② Permanent Magnet
- ③ Hybrid Type.

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Step Angle:-

$$\text{Resolution} = \frac{\text{No. of Steps.}}{\text{No. of Revolution of Rotor.}}$$

Step Size ($\Delta\theta$)

N_r = No. of Rotor Teeth.

m = No. of Stacks or stator phase

$$\text{Rotor tooth pitch} = \frac{360^\circ}{N_r}$$

$$\text{Step Size} = \Delta\theta = \frac{360^\circ / N_r}{m}$$

$$\Delta\theta = \frac{360^\circ}{m N_r}$$

$$\begin{aligned} \text{No. of steps in one Revolution} \\ &= \frac{360^\circ}{\Delta\theta} \quad \left(\text{When } N_s < N_r \right) \end{aligned}$$

When ($N_s > N_r$)

$$\text{Stator tooth pitch} = \frac{360^\circ}{N_s}$$

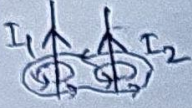
$$\text{Rotor tooth pitch} = \frac{360^\circ}{N_r}$$

$$\Delta\theta = \left(\frac{N_s - N_r}{N_s \cdot N_r} \right) \cdot 360^\circ$$

$$\text{Speed} = \frac{\text{Step Size} \times \text{Pulse per sec}}{360^\circ}$$

$$\text{Speed} = \frac{\Delta\theta \times \text{Pulse Rate}}{360^\circ}$$

Force between two parallel current carrying conductor.

Sl. No.	Direction	Field strength (H)	Force (F)	Flux Density (B)	Force	
1.	Same 	Decreased	Attraction	$B = \frac{\mu_0 I_1}{2\pi d}$	$F = \frac{\mu_0 I_1 I_2 l}{2\pi d}$ (N)	Force / metre $= \frac{2 \times 10^{-7} I_1 I_2}{d}$ (N)
2.	Opposite 	Increased	Repulsion			$l = \text{length}$ $d = \text{distance}$

Electro static Force (F)

$$F = \frac{q_1 q_2}{4\pi \epsilon_0 r^2 d^2}$$

$$\frac{1}{4\pi \epsilon_0} = 9 \times 10^9$$

Magnetic Attraction & Repulsion,

Force (F)

of current carrying conductor.

$$F = \frac{\mu_0 I_1 I_2 \cdot l}{2\pi d}$$

$$\frac{\mu_0}{2\pi} = 2 \times 10^{-7}$$

Magnetic force (F)

$$F = \frac{m_1 m_2}{4\pi \mu_0 \mu_r d^2}$$

Application of 1- ϕ M/c

- Hysteresis Motor $\rightarrow$ Tape deck, Turn table, precise audio equipment, elect. clock, (free from mech noise & vibration).
- Repulsion Motor $\rightarrow$ Traction.
- Servo Motor $\rightarrow$ Position control, CD, DVD, Robotics, Toy.
- Stepper Motor $\rightarrow$ 3D printing, Textile, Printing press, CNC, welding, Small Robotics.
- Reluctance Motor $\rightarrow$ clock timers, Signaling device, Phonograph, Recording.