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Internal Assesment Test – 3

Sub: Special Electrical Machines (Professional Elective)				Code: 17EE554
Date: 18/11/2019	Duration: 90 mins	Max Marks: 50	Sem: 5	Sections: A&B

Answer **ANY FIVE** full questions. Explain your notations explicitly and clearly.
Sketch figures wherever necessary. Good luck!

		Marks	OBE	
			CO	RBT
Q1.	Derive the emf equation of ac series motor	[10]	CO4	L2
Q2.	Derive the voltage equation of a dc servo motor and draw the equivalent circuit. Plot the torque vs current and speed vs current characteristics of dc series motor and dc shunt motor.	[10]	CO4	L2
Q3a.	With a neat sketch, explain the constructional details of a drag cup ac servo motor.	[6]	CO4	L2
Q3b.	List the applications of universal motors.	[4]	CO4	L1
Q4a.	Explain with circuit diagrams the following speed control methods of universal motor (i) resistance method; and (ii) auto-transformer method.	[6]	CO4	L2
Q4b.	List any four applications of single-phase reluctance motor.	[4]	CO4	L1
Q5.	Draw the phasor diagram of a permanent magnet axial flow (PMAF) motor. Neglecting armature resistance and losses, derive the equation of the power developed in PMAF motors.	[10]	CO5	L2
Q6a.	With a neat sketch, explain the construction of (i) homopolar DC Linear Motor (DCLM); and (ii) iron-cored DCLM.	[6]	CO5	L2
Q6b.	A vehicle is propelled by a linear induction motor (LIM). The motor has 100 poles with a pole pitch of 0.5 m. Find the vehicle speed in kmph when the vehicle is running with a slip of 0.25 at a frequency if 50 Hz.	[4]	CO5	L3
Q7a.	With neat sketches, explain the construction of (i) single-sided PMAF machine; and (ii) double-sided PMAF machine with internal permanent magnet (PM) rotor.	[6]	CO5	L2
Q7b.	Compare slotless and slotted linear synchronous motors (LSMs).	[4]	CO5	L1
Q8.	The thrust developed by a 3-phase LIM is 100 kN when running at 200 kmph. The supply frequency is 60 Hz and the pole pitch is 0.5 m. Determine the secondary copper loss.	[10]	CO5	L3

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ASSIGNMENT-3

ELECTRICAL AND ELECTRONICS ENGG [MR. KASHIF AHMED]

NAME :- ANINDITA BISWAS

CLASS :- '5' - 'A'

USN :- 1 CR17EE006

DUE DATE FOR SUBMISSION :- 20 NOVEMBER, 2019

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1) Derive the emf equation of ac series motor.

Soln Rotational emf.

Flux cut by 1 conductor in 1 revolution $= P\phi$

For N revolutions $= NP\phi$

Flux cut by 1 conductor per sec $= \frac{NP\phi}{60}$

Number of conductors $= \frac{Z}{A}$

Flux cut by $\frac{Z}{A}$ conductors / sec $= \frac{NP\phi Z}{60A} = E_r$

We know $\phi = \phi_m \sin\omega t$

$$E_r = \frac{ZNP\phi\ \phi_m \sin\omega t}{60A} = E_{rm} \sin\omega t$$

$$E_{rm} = \frac{ZN\phi_m P}{60A} \quad ; \quad E_{r(rms)} = \frac{E_{rm}}{\sqrt{2}}$$

Transformer emf

Turns / parallel path $= \frac{Z}{2A}$

Instantaneous X'er emf $= \frac{d}{dt}\left\{\frac{Z}{2A}\phi_m \sin\omega t\right\}$

$$= \frac{Z}{2A}\,\omega\phi_m \cos\omega t$$

$$= \frac{2\pi f \phi_m \cos\omega t \cdot Z}{2A}$$

$$E_t = \frac{\pi f \phi_m \cos\omega t\, Z}{A} \quad ; \quad E_{tm} = \frac{\pi f \phi_m Z}{A}$$

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$I_m = I \sin\omega t$

Instantaneous power $= e_b i = E_{bm} \sin\omega t \, I_m \sin\omega t$

$= E_{bm} I_m \sin^2\omega t$

$= E_{bm} I_m \frac{(1 - \cos 2\omega t)}{2}$

Average power $= \frac{E_{bm} I_m}{2}$

$E_{bm} = \frac{Z N \phi_m P}{60 A}$, $I_m = \sqrt{2} I$

$P_{avg} = \frac{Z N \phi_m P}{2 \times 60 A} \times \sqrt{2} I$

$\tau = \frac{P}{\omega} = \frac{Z N \phi_m P \times \sqrt{2} I}{2 \times 60 A \times \frac{2\pi N}{60}}$

$$\boxed{\tau = \frac{0.11254 \, Z \phi_m P I}{A}}$$

---

2) Derive the voltage equation of a dc servo motor and draw the equivalent circuit. Plot the torque vs current and speed vs current characteristics of a dc series motor and dc shunt motor.

Soln. Voltage equation

When the motor is running, the armature conductors cut the magnetic field and an emf is induced in the armature conductors due to change in armature conductors due to change in flux linkage. This emf has direction opposite to supply voltage and hence it is known as back emf.

Let P = numbers of poles.

Z = number of armature conductors.

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ϕ = flux per pole, Wb

N = Speed in rpm

A = number of parallel paths

The flux cut by an armature conductor / revolution

$d\phi = P\phi$

No. of rev / sec, $dt = \frac{N}{60}$

Flux cut by an armature conductor/sec $= \frac{P\phi N}{60}$

$\therefore$ emf induced in one conductor,

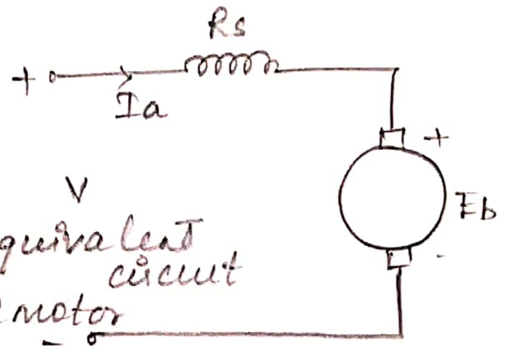
$$\frac{d\phi}{dt} = \frac{P\phi N}{60}.$$

Number of conductors per parallel path $= \frac{Z}{A}$

$\therefore$ emf induced /parallel path = emf induced in armature crossbrushes $= \frac{P\phi N}{60} \cdot \frac{Z}{A}$

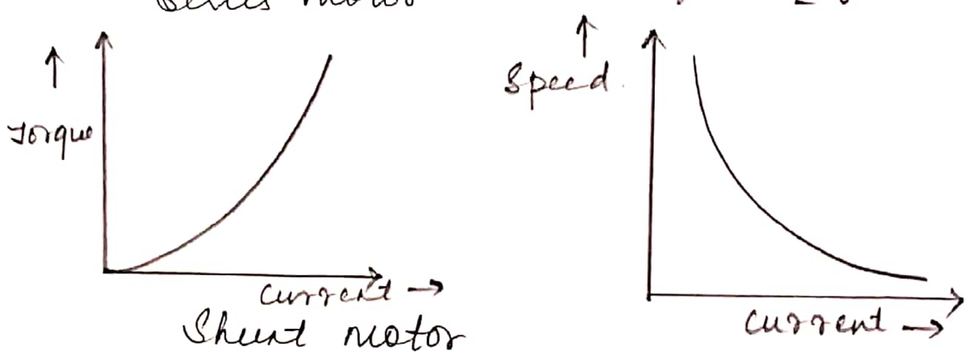
This is the back emf

$$E_b = \frac{\phi Z N P}{60A}.$$

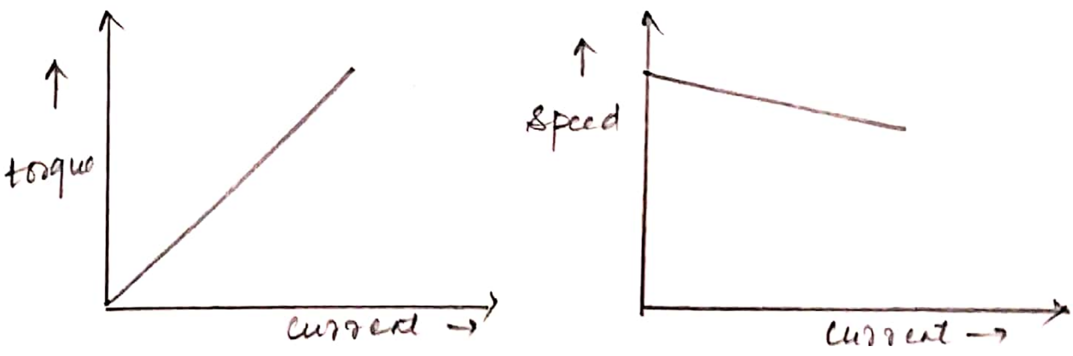


Equivalent circuit of DC motor

Series motor

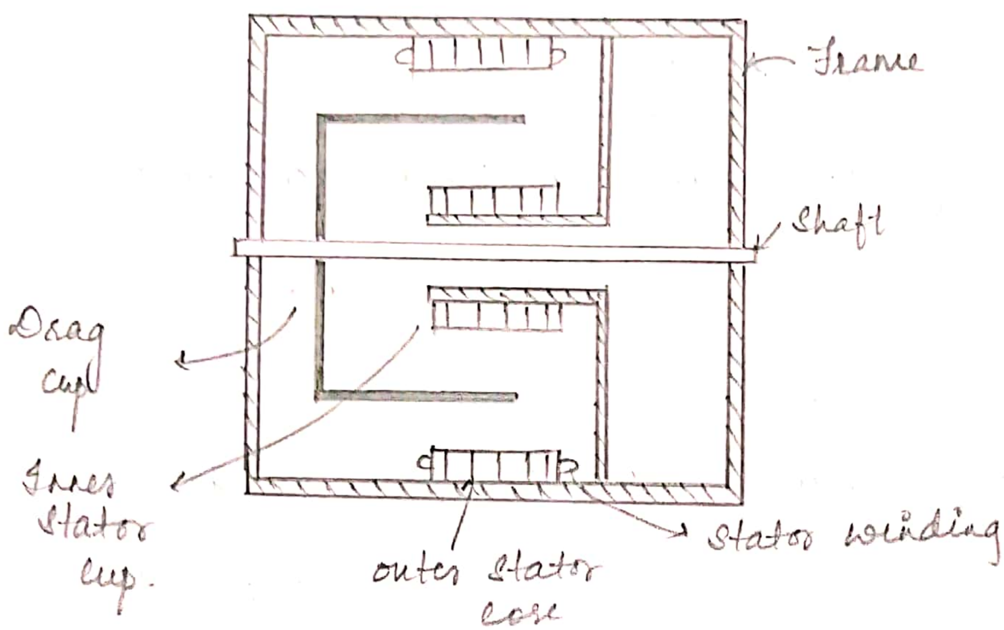


Shunt motor



3) a) Write neat sketch, explain the constructional details of a drag cup ac servo motor.

Soln Drag cup servomotor



→ Has an outer core carrying both winding and inner stator core.
→ Outer core is supported by motor frame.
→ Inner and outer stator cores are of cylindrical shape.
→ Core are made up of laminated steel sheets
→ Drag cup is mounted on the shaft.
→ Made up of conducting material
→ Construction in the form of hollow cylinder with one side open.
→ Thin and light, inertia is very small and considerable with one side open.
→ Thin air gap (ie) air gap between inner and outer cores kept minimum.
→ Compared to solid iron and squirrel cage, drag cup type has higher effective gap.

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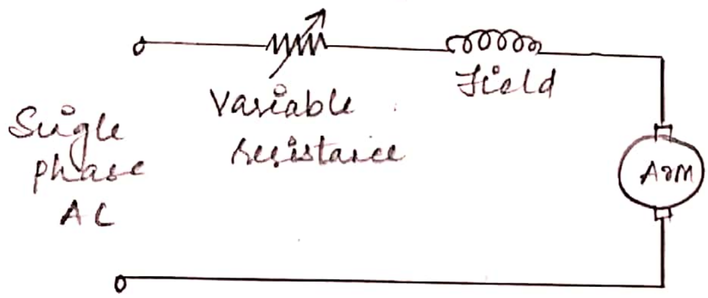
3) b) List the applications of universal motors.

Soln. → Centrifugal blowers in vaccum cleaners.
→ Food mixer and blender
→ Electronic typewriters
→ Electric Locomotives
→ Camera.

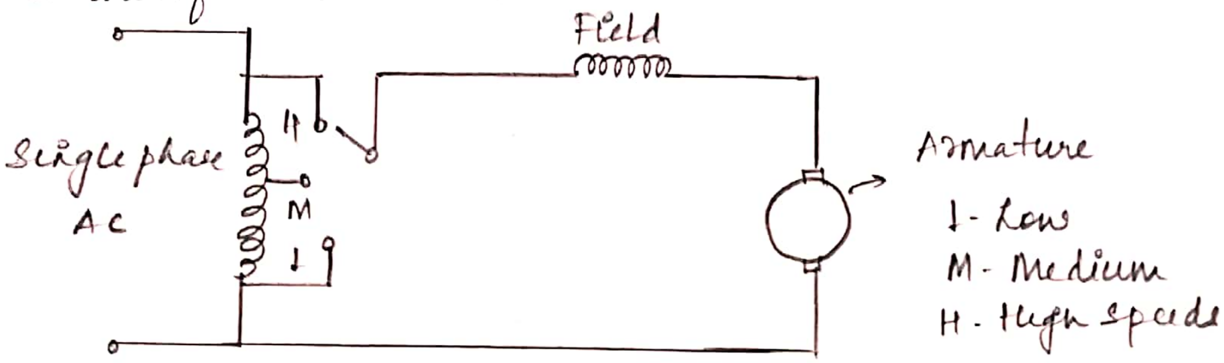
4) a) Explain with circuit diagram the following speed control methods of universal motor (i) resistance method (ii) Auto-transformer method.

Soln. (i) Resistance method.

In this method, variable resistance is connected in series with the motor. The resistance in the circuit decides the speed of the motor. This method of speed control is adopted in sewing machines.



(ii) Auto transformer method.



An autotransformer is used across supply.
The autotransformer has tapping points

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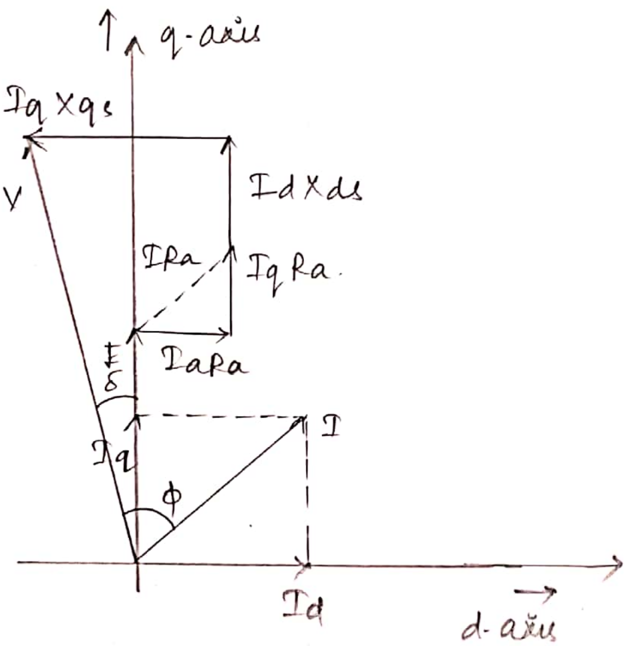
Depending on speed requirement, supply from different tappings is given to motor.

4) b) List any four applications of single-phase reluctance motor.

Soln.
- → Record players
- → Computer peripherals – harddisk, drives.
- → Recording instruments
- → Signalling devices.

5) Draw the phasor diagram of a permanent magnet axial flow (PMAF) motor. Neglecting armature resistance and losses, derive the equation of power developed in PMAF motors.

Soln. In PMAF phasor diagram,



I = stator current

I_d = direct axis component of stator current

I_q = quadrature axis component of stator current

X_{ds} = direct axis synchronous reactance

X_{qs} = quadrature axis synchronous reactance.

R_a = stator resistance

E = emf due to PM.

V = stator terminal voltage

δ = load angle

ϕ = power factor angle.

Neglecting armature resistance R and losses, the

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power developed is

$$P = VI\cos\phi$$

$$V\sin\delta = I_q X_{qs}.$$

$$V\cos\delta = E + I_d X_{ds}.$$

$$I_q = \frac{V\sin\delta}{X_{qs}}.$$

$$I_d = \frac{V\cos\delta - E}{X_{ds}}$$

$$I\cos\phi = I_q\cos\delta - I_d\sin\delta$$

$$= \frac{V\sin\delta\cos\delta}{X_{qs}} - \frac{(V\cos\delta - E)\sin\delta}{X_{ds}}$$

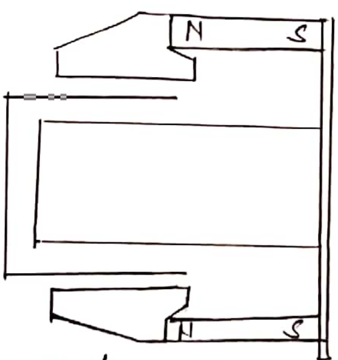
$$P = V\left\{\frac{V\sin\delta\cos\delta}{X_{qs}} - \frac{(V\cos\delta - E)\sin\delta}{X_{ds}}\right\}$$

$$= \frac{EV\sin\delta}{X_{ds}} + \frac{V^2\sin 2\delta(X_{ds} - X_{qs})}{2X_{ds}X_{qs}}.$$

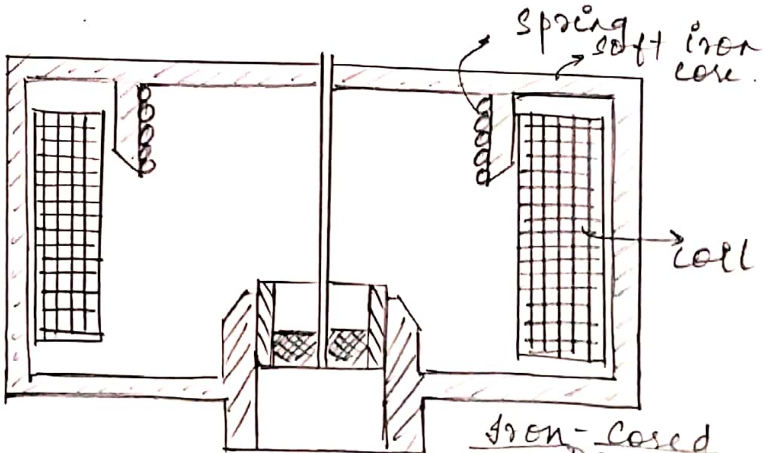
$$\boxed{P = \frac{EV\sin\delta}{X_{ds}} + \frac{V^2(X_{ds} - X_{qs})\sin 2\delta}{2X_{ds}X_{qs}}}$$

6b a) With a neat sketch, explain the construction of i) homopolar DC linear motor (DCLM) and (ii) iron cored DCLM.

Soln.



Homopolar DCLM



Iron-Cored DCLM

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- Stator
  - → Serves as body.
  - → Laminated steel
  - → Conductors wound in transverse slots.

- Slider
  - → Contains one or more set of magnets
  - → Commutation components
  - → Bearing surface
  - → Body completes magnetic flux path
- Type.
  - → Homopolar (short-stroke low thrust applications)
  - → Heteropolar (short-stroke low thrust applications)
  - → Tubular DCLM.

6b b) A vehicle is propelled by a linear induction motor (LIM). The motor has 100 poles with a pole pitch of 0.5m. Find the vehicle speed in kmph when the vehicle is running with a slip of 0.25 at a frequency of 50 Hz.

Soln. Given $f = 50Hz$, $s = 0.25$, $\tau = 0.5m$

We know $V_a = V_s(1-s)$

$V_s = 2f\tau$

$V_s = 2 \times 50 \times 0.5 = 50 m/s$.

$V_a = 50(1-0.25) = 37.5 m/s$.

$37.5 \times \frac{3600}{1000} = 135 km/hr$.

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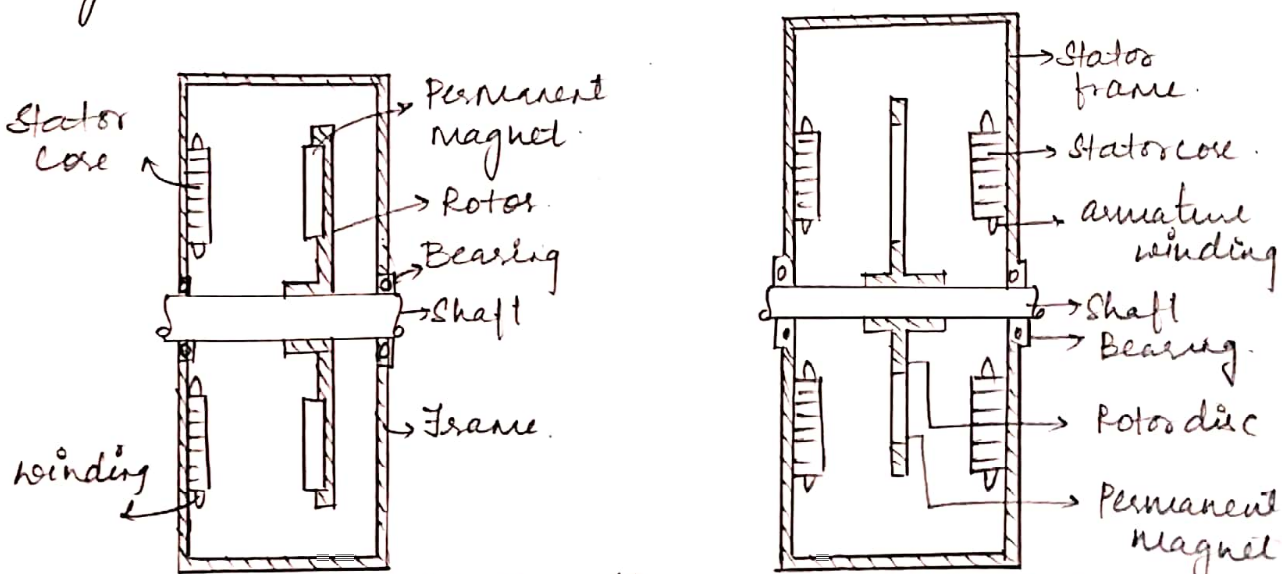
7) a) With neat sketches, explain the construction of i) single sided PMAF machine and ii) double-sided PMAF machine with internal permanent magnet PM motor.

Soln. ◦ Single sided PMAF

→ Simple construction
→ Less torque.
→ Armature winding in stator slot
→ PM fixed on non-magnetic material

◦ Double sided PMAF

→ More torque
→ Armature winding in stator slot
→ Armature winding in series or parallel.
→ preferred in series connection as it produces equal and opposite axial attractive force.
→ PM fixed on non-magnetic rotor disc using glue or is embedded.



Single sided PMAF machine   Double sided PMAF

7) b) Compare slotless and slotted linear synchronous

motors (LSM's).

soln

Slotless LSM	Slotted LSM.
→ Higher efficiency in the higher speed range	→ Higher efficiency in lower speed range.
→ Lower winding cost	→ Higher thrust density.
→ Lower thrust pulsation	→ Lower input current.
→ Lower acoustic noise.	→ Less number of permanent magnets.

Q. The thrust developed by a 3 phase LIM is 100 KN when running at 200 kmph. The supply frequency is 60Hz and the pole pitch is 0.5m. Determine the secondary copper loss.

soln. Given $\tau = 0.5m$, $f = 60Hz$, $F = 100\,000N$,

$V_a = 200\ km/hr = 200 \times \frac{5}{18} = 55.55\ m/s$

Copper Loss = $F s V_s$

$V_s = 2f\tau = 2 \times 60 \times 0.5 = 60\ m/s$

$s = 1 - \frac{V_a}{V_s} = 1 - \frac{55.55}{60} = 0.074$

Copper loss $= 100\,000 \times 0.074 \times 60 = 0.44MW = 444\ kW$

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