Question 1:Design an 3 hall sensor based Inner runner Rotor Brushless DC (BLDC) Motor with proper analytical modeling and FEA simulation, considering the following specifications:
Specifications:

Motor Power: 300W
Voltage: 24V
Efficiency: 95%
Power Factor: 0.95
Base RPM: 3000
Motor Outer Diameter: <70mm
Motor Stack Length: <35mm

General Data	Value
Rated Output Power (kW)	0.3
Rated Voltage (V)	24
Number of Poles	8
Given Rated Speed (rpm)	3000
Frictional Loss (W)	1
Windage Loss (W)	1
Rotor Position	Inner
Type of Load	Constant Power
Type of Circuit	Y3
Lead Angle of Trigger in Elec. Degrees	0
Trigger Pulse Width in Elec. Degrees	120
One-Transistor Voltage Drop (V)	0.1
One-Diode Voltage Drop (V)	0.7
Operating Temperature ©	60

Full-Load Parameter	Value
Average Input Current (A)	13.1454
Root-Mean-Square Armature Current (A)	11.8261
Armature Thermal Load (A^2/mm^3)	69.3234
Specific Electric Loading (A/mm)	19.3595
Armature Current Density (A/mm^2)	3.58084
Frictional and Windage Loss (W)	4.47993
Iron-Core Loss (W)	0.00127531
Armature Copper Loss (W)	7.24261
Transistor Loss (W)	2.77143
Diode Loss (W)	1.00135
Total Loss (W)	15.4966
Output Power (W)	299.993
Input Power (W)	315.49
Efficiency (%)	95.0881
Rated Speed (rpm)	4342.31
Rated Torque (N.m)	0.659723
Locked-Rotor Torque (N.m)	26.6894
Locked-Rotor Current (A)	688.594

Stator Data	Value
Number of Stator Slots	12
Outer Diameter of Stator (mm)	70
Inner Diameter of Stator (mm)	35

Type of Stator Slot	3
Stator Slot hs0 (mm)	0.5
Stator Slot hs1 (mm)	0.766201
Stator Slot hs2 (mm)	13.6903
Stator Slot bs0 (mm)	2.5
Stator Slot bs1 (mm)	5.1542
Stator Slot bs2 (mm)	12.4908
Stator Slot rs (mm)	0
Top Tooth Width (mm)	4.71239
Bottom Tooth Width (mm)	4.71239
Skew Width (Number of Slots)	0
Length of Stator Core (mm)	35
Stacking Factor of Stator Core	0.95
Type of Steel	steel_1010
Slot Insulation Thickness (mm)	0
Layer Insulation Thickness (mm)	0
End Length Adjustment (mm)	0
Number of Parallel Branches	2
Number of Conductors per Slot	30
Type of Coils	21
Average Coil Pitch	1
Number of Wires per Conductor	1
Wire Diameter (mm)	1.45
Wire Wrap Thickness (mm)	0.2
Slot Area (mm^2)	124.965
Net Slot Area (mm^2)	109.177
Limited Slot Fill Factor (%)	75
Stator Slot Fill Factor (%)	74.8098
Coil Half-Turn Length (mm)	46.0127

Rotor Data	Value
Minimum Air Gap (mm)	0.5
Inner Diameter (mm)	14
Length of Rotor (mm)	35
Stacking Factor of Iron Core	0.95
Type of Steel	steel_1010
Polar Arc Radius (mm)	17
Mechanical Pole Embrace	0.7
Electrical Pole Embrace	0.740217
Max. Thickness of Magnet (mm)	2.5
Width of Magnet (mm)	9.22898
Type of Magnet	NdFe30
Type of Rotor	2
Magnetic Shaft	Yes

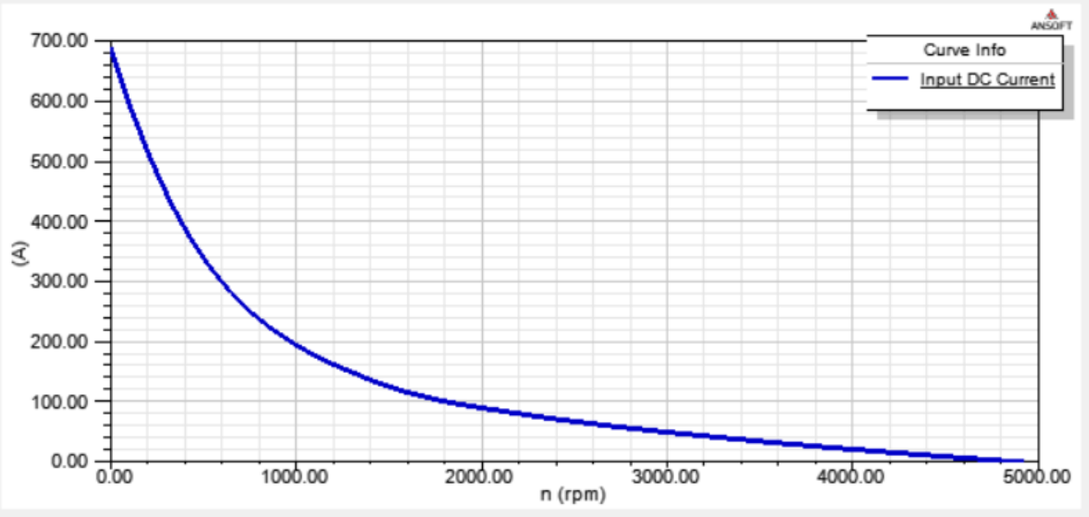
Permanent Magnet Parameter	Value
Residual Flux Density (Tesla)	1.1
Coercive Force (kA/m)	838
Maximum Energy Density (kJ/m^3)	230.45
Relative Recoil Permeability	1.0446
Demagnetized Flux Density (Tesla)	0.315082

Recoil Residual Flux Density (Tesla)			1.1
Material	Density (kg/m^3)	Weight (kg)	Consumption (kg)
Armature Copper	8900	0.243442	-
Permanent Magnet	7550	0.0495064	-
Armature Core Steel	7872	-	1.18433
Rotor Core Steel	7872	-	0.210507
Total Net Weight	-	0.788518	-

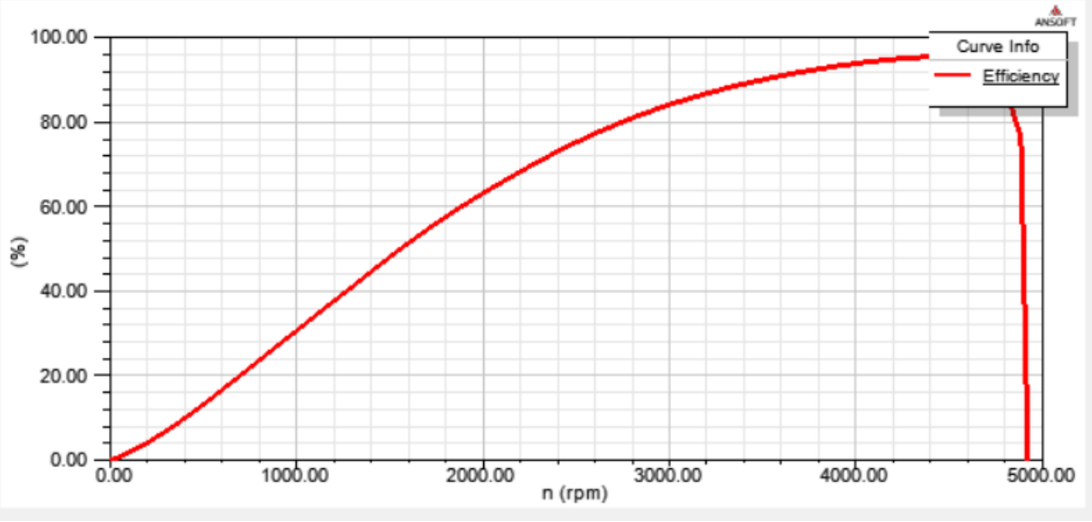
No-Load Magnetic Parameter	Value
Stator-Teeth Flux Density (Tesla)	1.59068
Stator-Yoke Flux Density (Tesla)	1.64131
Rotor-Yoke Flux Density (Tesla)	0.556615
Air-Gap Flux Density (Tesla)	0.757964
Magnet Flux Density (Tesla)	0.859442
Stator-Teeth By-Pass Factor	0.00649536
Stator-Yoke By-Pass Factor	0.00025605
Rotor-Yoke By-Pass Factor	5.65469e-005
Stator-Teeth Ampere Turns (A.T)	58.7276
Stator-Yoke Ampere Turns (A.T)	28.3506
Rotor-Yoke Ampere Turns (A.T)	1.59408
Air-Gap Ampere Turns (A.T)	369.44
Magnet Ampere Turns (A.T)	-458.153
Armature Reactive Ampere Turns (A.T)	1346.33
Leakage-Flux Factor	1
Correction Factor for Magnetic Circuit Length of Stator Yoke	0.419397
Correction Factor for Magnetic Circuit Length of Rotor Yoke	0.795235
No-Load Speed (rpm)	4986.64
Cogging Torque (N.m)	0.159887

Transient FEA Input Parameter	Value
Armature Winding	
Number of Turns	60
Parallel Branches	2
Terminal Resistance (ohm)	0.0172621
End Leakage Inductance (H)	9.75434e-008
2D Equivalent Value	
Equivalent Model Depth (mm)	35
Equivalent Stator Stacking Factor	0.95
Equivalent Rotor Stacking Factor	0.95
Equivalent Br (Tesla)	1.1
Equivalent Hc (kA/m)	838
Estimated Rotor Moment of Inertia (kg m^2)	3.58161e-005

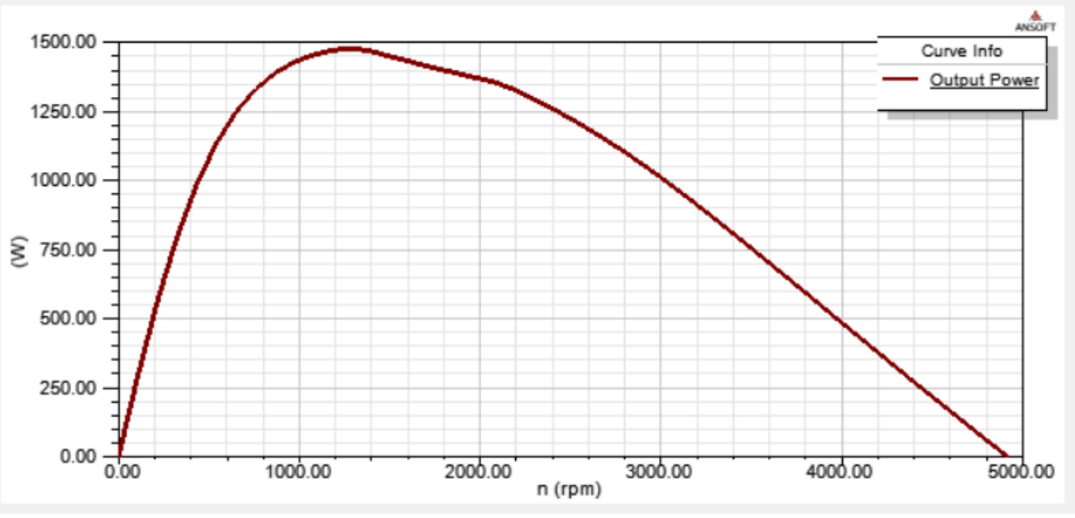
Name: Input DC Current vs Speed

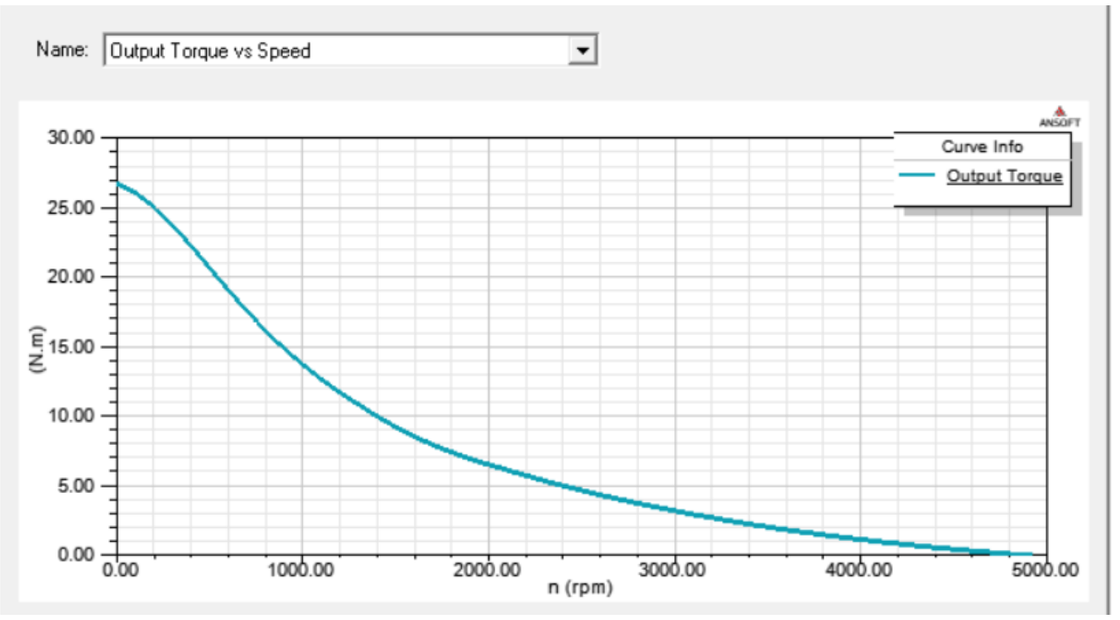


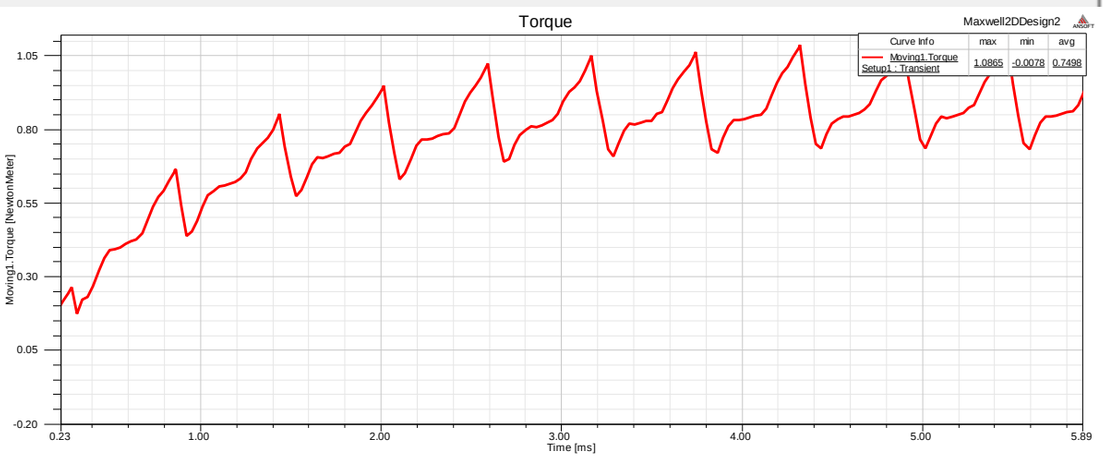
Name: Efficiency vs Speed

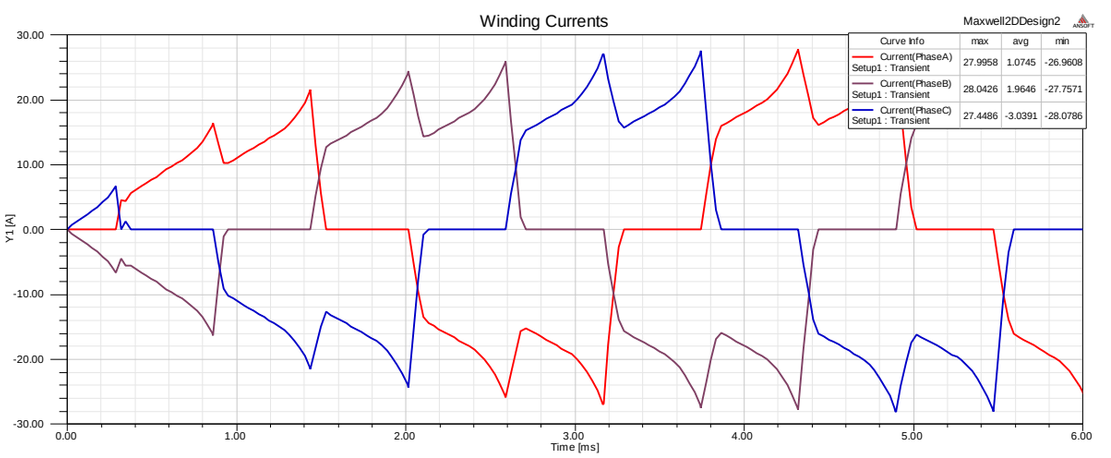


Name: Output Power vs Speed

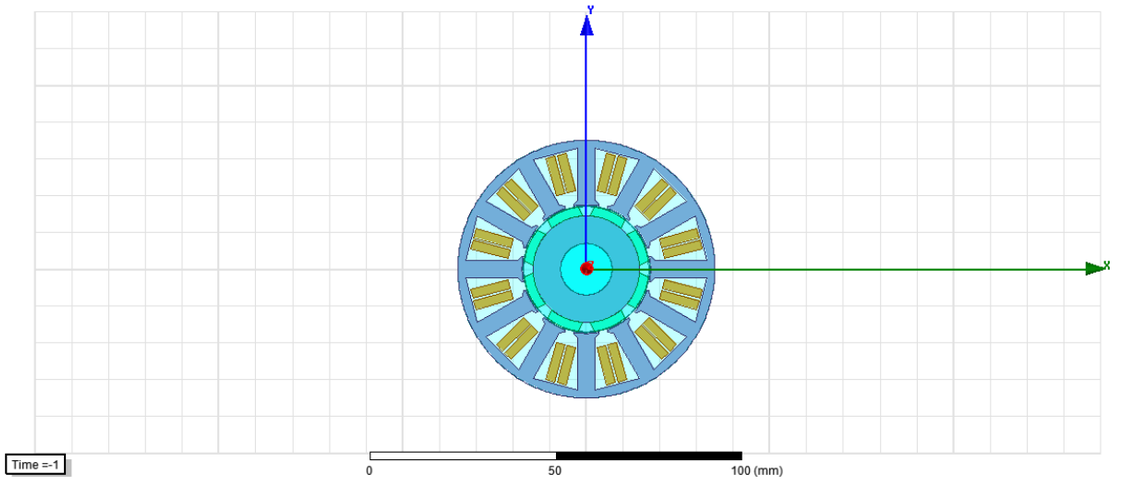



Name: Output Torque vs Speed
ANSOFT
Curve Info
Output Torque
30.00
25.00
20.00
15.00
10.00
5.00
0.00
(N.m)
0.00
1000.00
2000.00
3000.00
4000.00
5000.00
n (rpm)

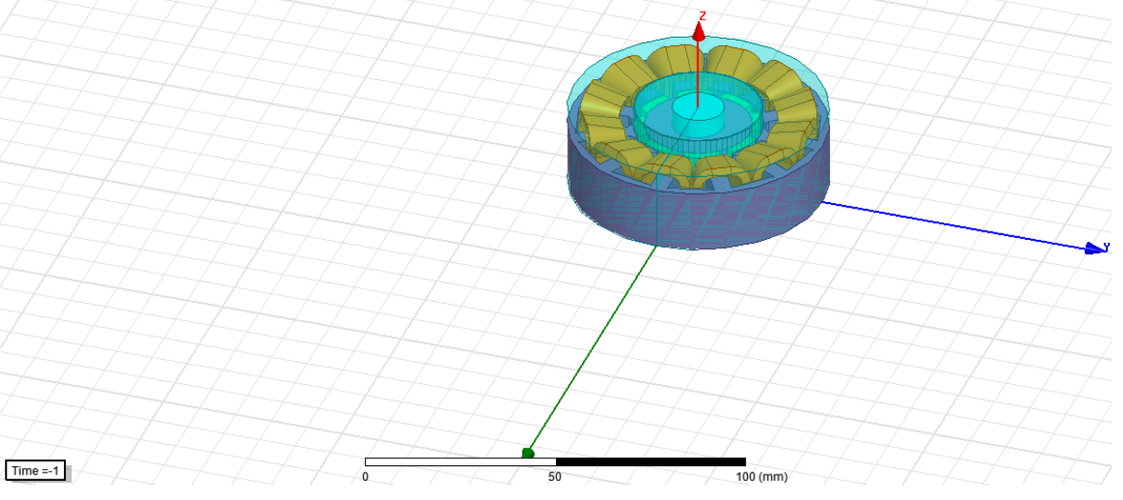

Torque
Maxwell2DDesign2
Curve Info | max | min | avg
Moving1.Torque
Setup1 : Transient | 1.0865 | -0.0078 | 0.7498
1.05
0.80
0.55
0.30
0.05
-0.20
Moving1.Torque [NewtonMeter]
0.23
1.00
2.00
3.00
4.00
5.00
5.89
Time [ms]


Winding Currents
Maxwell2DDesign2
Curve Info | max | avg | min
Current(PhaseA)
Setup1 : Transient | 27.9958 | 1.0745 | -26.9608
Current(PhaseB)
Setup1 : Transient | 28.0426 | 1.9646 | -27.7571
Current(PhaseC)
Setup1 : Transient | 27.4486 | -3.0391 | -28.0786
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
Y1 [A]
0.00
1.00
2.00
3.00
4.00
5.00
6.00
Time [ms]

2-D Design of Motor:



3-D Design of Motor:



efficiency = 95%.

Output power = 300W

$$\frac{300}{x} \times 100 = 95$$

$$P_{in} = \frac{300 \times 100}{95}$$

$$P_{in} = 315.78\ W$$

Terminal current.

$$I_t = \frac{315.78}{24}$$

$$I_t = 13.15\ A$$

Parallel paths

$$I_{peak} = I_t$$

$$I_{ph\ rms} = \sqrt{\frac{2}{3}}\ I_{peak}$$

$$I_{ph\ rms} = 10.736\ A$$

$$I_C = \frac{I_{ph}}{N_P}$$

N_P → No of parallel path.

No of coils N_C = No of stator slots

No of coils in each phase

$$= \frac{N_S}{3}$$

N_S = no of stator slots

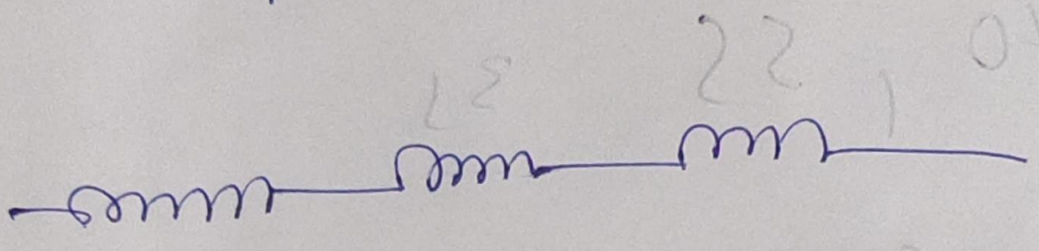
m = no of phases.

N_D

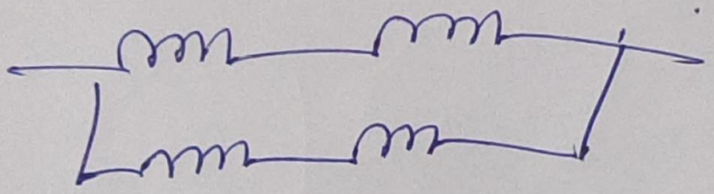
$$N_{tph} = N_{tc} \times \frac{N_S}{m} \times \frac{1}{N_D}$$

↓
no of turns

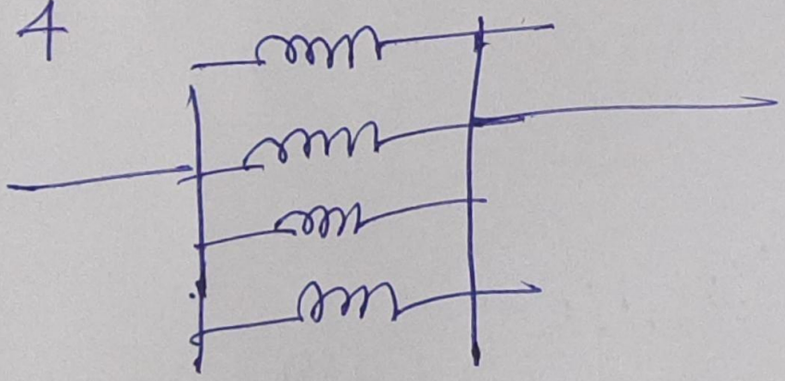
If Np parellel path



N = 2



N = 4



Winding = 2 , whole , 1 , 60 , 8 .

0.5 1 8.2 2.5 5.6

4 , Iu 10 2 3000

120 2 1

Stat

70 , 55 35

6.9

~~30 slots~~.

8 poles , 12 slots , 30 conductors each

18 full (whole) coiled.

parallel paths 2