Question 2:Design an 3 hall sensor based outer 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: <50mm

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)	2
Windage Loss (W)	2
Rotor Position	Outer
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 (C)	60

Full Load Data	Value
Average Input Current (A)	14.6938
Root-Mean-Square Armature Current (A)	12.675
Armature Thermal Load (A^2/mm^3)	467.782
Specific Electric Loading (A/mm)	21.3596
Armature Current Density (A/mm^2)	21.9004
Frictional and Windage Loss (W)	6.46288
Iron-Core Loss (W)	0.000289665
Armature Copper Loss (W)	42.456
Transistor Loss (W)	3.02055
Diode Loss (W)	0.575113
Total Loss (W)	52.5148
Output Power (W)	300.135
Input Power (W)	352.65
Efficiency (%)	85.1085
Rated Speed (rpm)	3764.89
Rated Torque (N.m)	0.761266
Locked-Rotor Torque (N.m)	6.61458
Locked-Rotor Current (A)	134.939

Stator Data	Value
Number of Stator Slots	12

Outer Diameter of Stator (mm)	34
Inner Diameter of Stator (mm)	18
Type of Stator Slot	4
Stator Slot hs0 (mm)	0.5
Stator Slot hs1 (mm)	0
Stator Slot hs2 (mm)	4.36604
Stator Slot bs0 (mm)	2.5
Stator Slot bs1 (mm)	4.67951
Stator Slot bs2 (mm)	2.33975
Stator Slot rs (mm)	0
Top Tooth Width (mm)	3.99715
Bottom Tooth Width (mm)	3.99715
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)	0.607
Wire Wrap Thickness (mm)	0
Slot Area (mm^2)	16.5732
Net Slot Area (mm^2)	15.3232
Limited Slot Fill Factor (%)	75
Stator Slot Fill Factor (%)	72.1356
Coil Half-Turn Length (mm)	41.1477

Rotor Data	Value
Minimum Air Gap (mm)	0.5
Outer Diameter (mm)	50
Length of Rotor (mm)	35
Stacking Factor of Iron Core	0.95
Type of Steel	steel_1010
Polar Arc Radius (mm)	17.5
Mechanical Pole Embrace	0.7
Electrical Pole Embrace	0.694513
Max. Thickness of Magnet (mm)	2.5
Width of Magnet (mm)	9.50042
Type of Magnet	NdFe35
Type of Rotor	1
Magnetic Shaft	Yes

Permanent Magnet Data	Value
Residual Flux Density (Tesla)	1.23

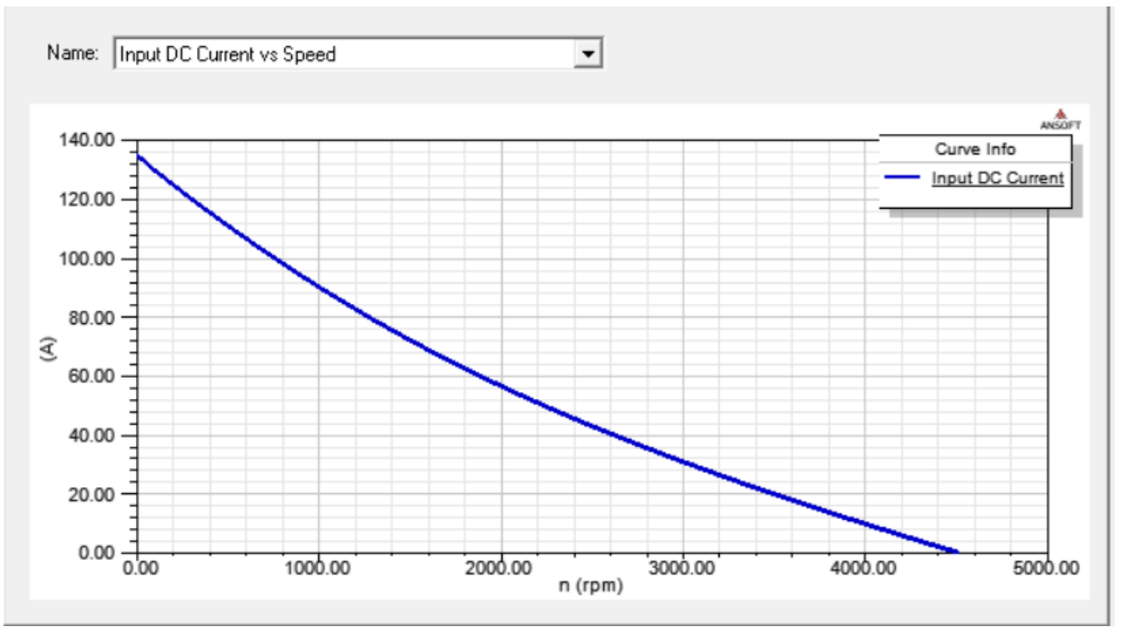
Coercive Force (kA/m)	890
Maximum Energy Density (kJ/m^3)	273.675
Relative Recoil Permeability	1.09981
Demagnetized Flux Density (Tesla)	0.821076
Recoil Residual Flux Density (Tesla)	1.23
Recoil Coercive Force (kA/m)	890

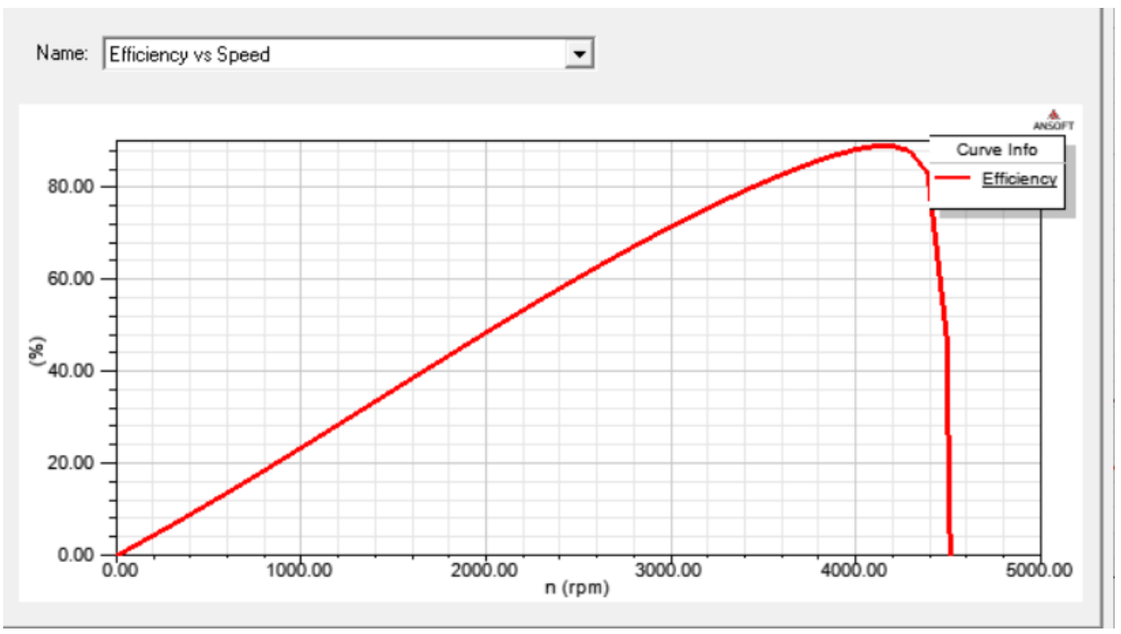
Material	Density (kg/m^3)	Weight (kg)	Consumption (kg)
Armature Copper	8900	0.038151	-
Permanent Magnet	7400	0.0533973	-
Armature Core Steel	7872	0.118982	0.28143
Rotor Core Steel	7872	0.185016	0.453809
Total Net Weight	-	0.395546	-

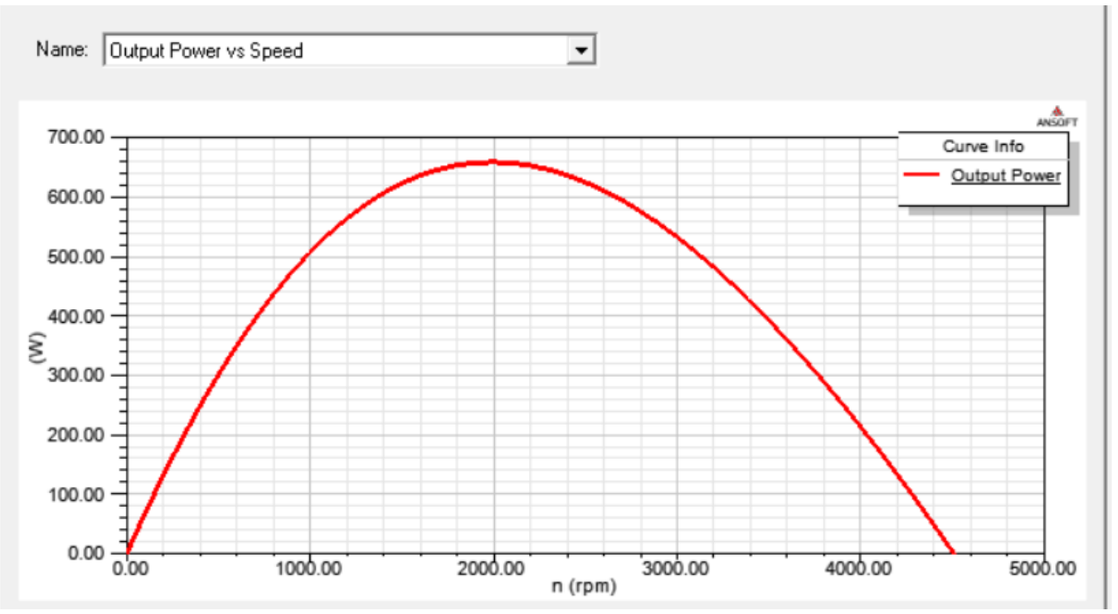
No-Load Magnetic Data	Value
Stator-Teeth Flux Density (Tesla)	2.07322
Stator-Yoke Flux Density (Tesla)	0.367495
Rotor-Yoke Flux Density (Tesla)	0.891834
Air-Gap Flux Density (Tesla)	0.888288
Magnet Flux Density (Tesla)	0.891795
Stator-Teeth By-Pass Factor	0.0248351
Stator-Yoke By-Pass Factor	6.14971e-005
Rotor-Yoke By-Pass Factor	5.68177e-005
Stator-Teeth Ampere Turns (A.T)	183.073
Stator-Yoke Ampere Turns (A.T)	0.692669
Rotor-Yoke Ampere Turns (A.T)	5.10189
Air-Gap Ampere Turns (A.T)	423.092
Magnet Ampere Turns (A.T)	-611.794
Armature Reactive Ampere Turns at Start Operation (A.T)	265.653
Leakage-Flux Factor	1
Correction Factor for Magnetic Circuit Length of Stator Yoke	0.850832
Correction Factor for Magnetic Circuit Length of Rotor Yoke	0.768587
No-Load Speed (rpm)	4585.03
Cogging Torque (N.m)	0.126369

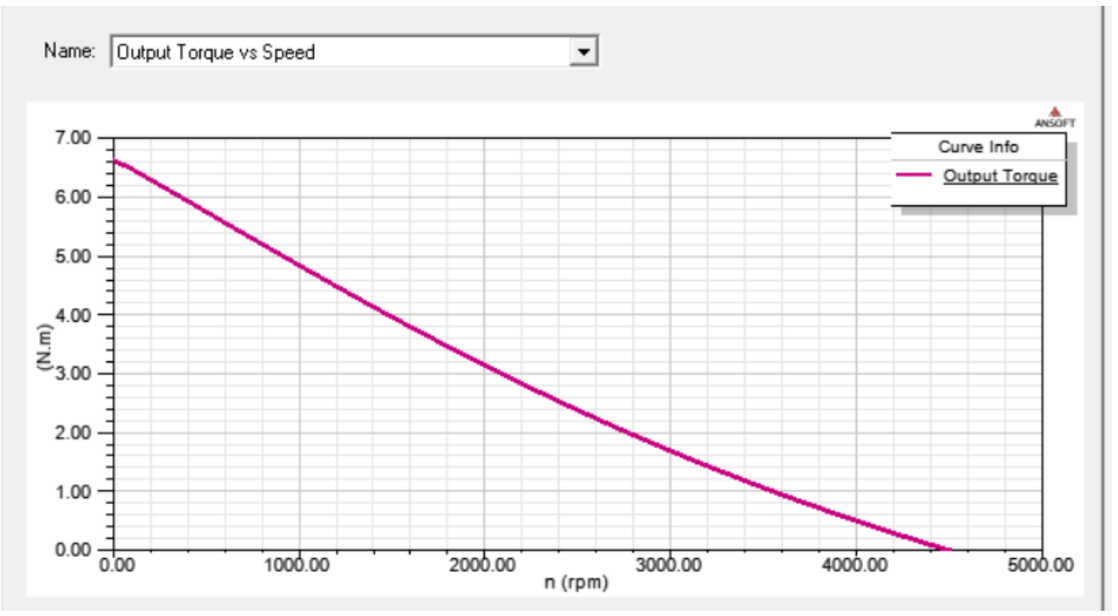
Transient FEA Input Data	Value
Armature Winding	

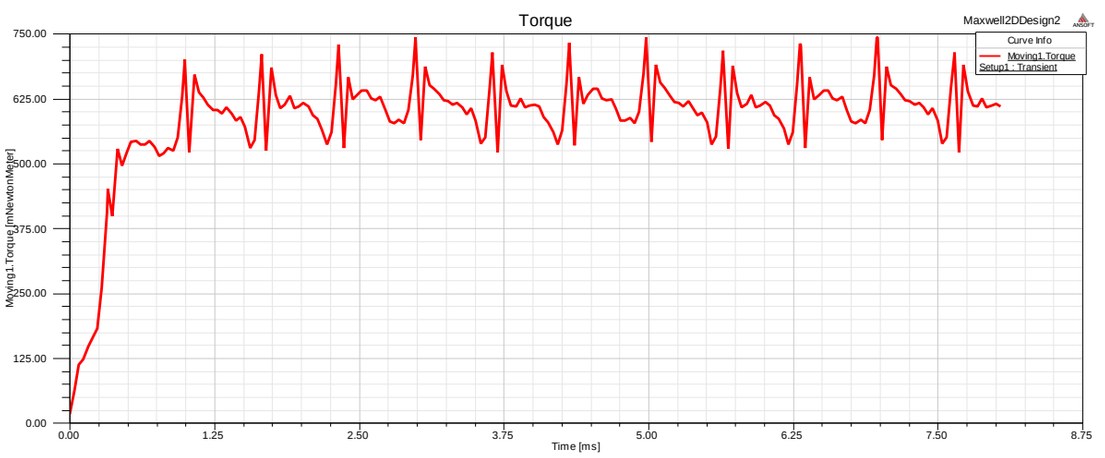
Number of Turns	60
Parallel Branches	2
Terminal Resistance (ohm)	0.0880887
End Leakage Inductance (H)	-1.70735e-007
2D Equivalent Value	
Equivalent Model Depth (mm)	35
Equivalent Stator Stacking Factor	0.95
Equivalent Rotor Stacking Factor	0.95
Equivalent Br (Tesla)	1.23
Equivalent Hc (kA/m)	890
Estimated Rotor Moment of Inertia (kg m^2)	0.000164018



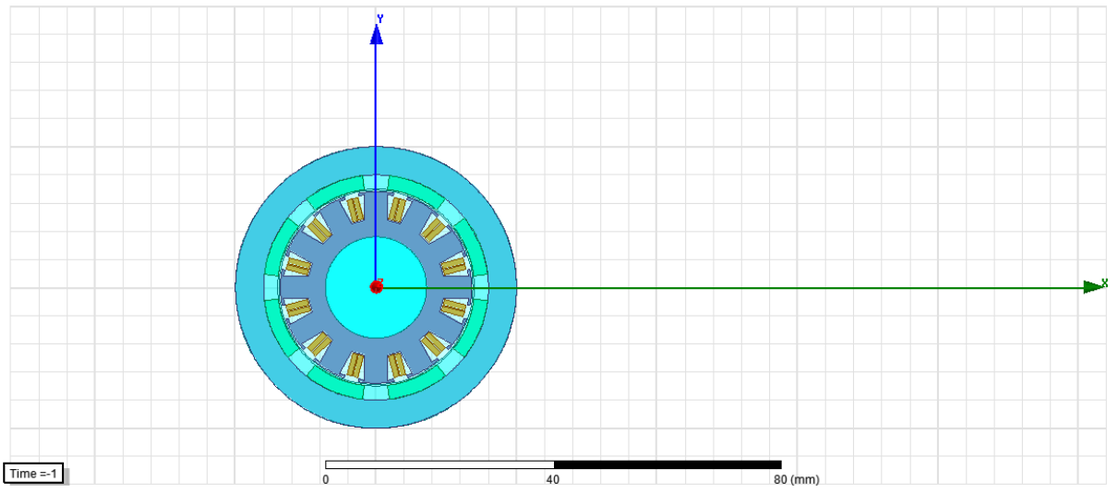



Name: Output Power vs Speed
ANSOFT
Curve Info
Output Power
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
(W)
0.00
1000.00
2000.00
3000.00
4000.00
5000.00
n (rpm)

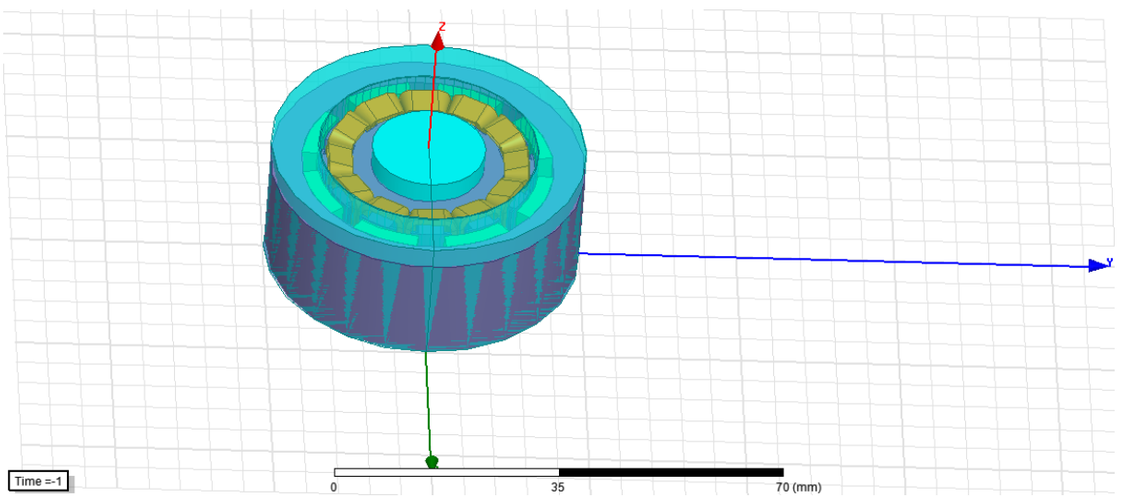

Name: Output Torque vs Speed
ANSOFT
Curve Info
Output Torque
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
(N.m)
0.00
1000.00
2000.00
3000.00
4000.00
5000.00
n (rpm)


Torque
Maxwell2DDesign2
ANSOFT
Curve Info
Moving1.Torque
Setup1 : Transient
750.00
625.00
500.00
375.00
250.00
125.00
0.00
Moving1.Torque [mNewtonMeter]
0.00
1.25
2.50
3.75
5.00
6.25
7.50
8.75
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

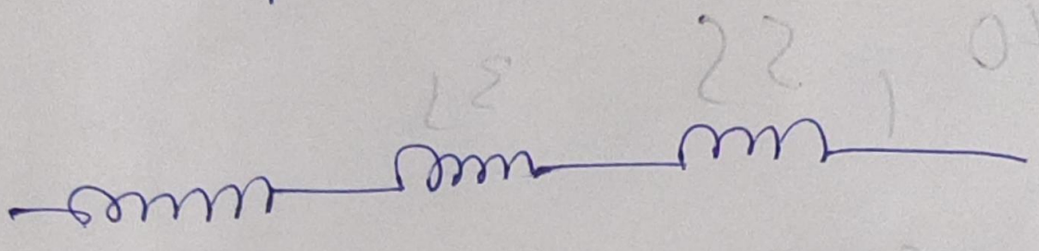
m = no of phases.

N_D

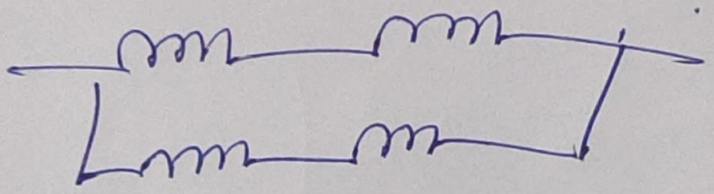
$$N_{tph} = N_{tc} \times \frac{N_S}{m} \times \frac{1}{N_D}$$

↓
no of turns

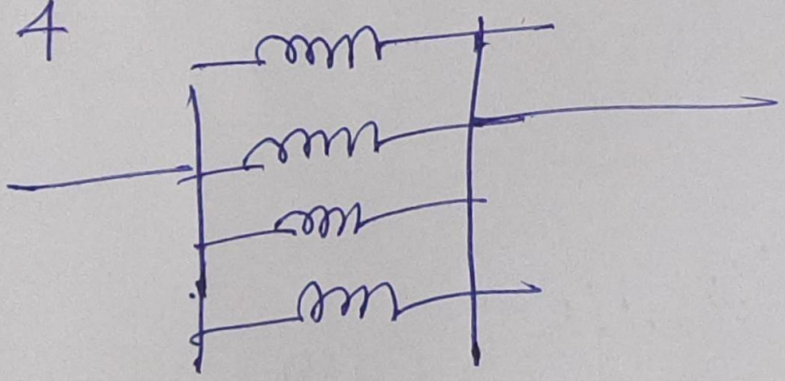
If Np parellel path



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

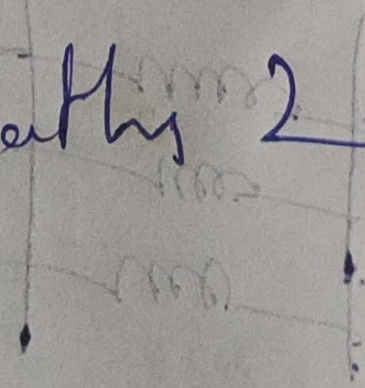
6.9

~~30 slots~~.

8 poles , 12 slots , 30 conductors each

18 full (whole) coiled.

parallel paths 2



for outer rotor

rotor inner diameter > stator outer diameter

2 parallel paths

8pole – 12 slots

30 conductors.

Steel 1010 material

Nd Fe 30 or NdFe35 magnet

24V 300V 95%