IJARCCE
ISSN (Online) 2278-1021
ISSN (Print) 2319-5940
International Journal of Advanced Research in Computer and Communication Engineering
Vol. 8, Issue 9, September 2019

Design and Analysis of Permanent Magnet Brushless DC Motor for Solar Vehicle using MATLAB

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Abstract: This paper presents style and performance analysis of static magnet Brushless DC motor of 2 kW utilized in star vehicle and hybrid electrical vehicle. Finite Component Methodology (FEM) is employed for deciding the performance characteristics of motor. Static magnet brushless DC motor, style and its dynamic performance analysis is finished on RM skilled then its magnetic attraction studies has done on Maxwell 3D.In last motor is analyze by varied the lead angle up to the mark circuit

Keywords: Static magnet brushless DC motor, FEM method, MatLab software

I. INTRODUCTION

The power sector veteran its largest annual increase in capability ever, with important growth altogether regions. Wind and star PV had record additions for the second consecutive year in step with world standing report 2016. Developing countries (e.g., Kenya, African country and Tanzania in Africa; China, Asian nation and Kingdom of Nepal in Asia; Brazil and South American nation in Latin America) area unit seeing speedy enlargement of small-scale renewable systems, together with renewable-based mini-grids, to supply electricity for folks living off from the grid.

India's current alternative energy put in capability is 4879 MW. To push electricity generation victimization alternative energy Government of Asian nation launched Nehru National star Mission in January 2010. The target is to attain large-scale readying of alternative energy Systems and additionally to help domestic production of crucial raw materials, elements and product to attain grid parity by 2022.

There are a unit range of benefits of electrical vehicle over standard burning energy cars. By victimization electrical vehicle pollution and inexperienced house emission impact will be reduced with massive scale. Dependency on non-renewable energy sources will be bated, that area unit restricted in nature. A BLDC motor is taken into account to be a high performance motor that's capable of providing massive amounts of torsion over a colossal speed varies [3].BLDC motors don't have brushes (hence the name "brushless DC") and should be electronically commutated.

Advantages-

•High Speed Operation – A BLDC motor will operate at speeds higher than 10500 rates below loaded and unloaded conditions.

•Responsiveness Acceleration – Inner rotor Brushless DC motors have low rotor inertia, permitting them to accelerate, decelerate, and reverse direction quickly.

•High Power Density – BLDC motors have the very best running torsion per cubic content unit of any DC motor.

•High dependableness – BLDC motors don't have brushes, which means they're additional reliable and have life expectations of over 10,000 hours. This leads to fewer instances of replacement or repair and fewer overall down time for your project.

II. FINITE COMPONENT METHODOLOGY

There are a unit range of techniques that are developed to unravel magnetic attraction connected issues not amenable to actual resolution. The Finite component methodology is employed to convert the complicated partial equation into nonlinear pure mathematics equation the finite component methodology will be applied to the vector Baron Hermann Ludwig Ferdinand von Helmholtz differential equation that comes from the Maxwell's equations or it will be derived from a scalar- vector potential formulation of the fields. There are a unit kind of business geometrical modelling tools to accurately model any three–dimensional pure mathematics and to come up with the desired mesh with any reasonably components like triangles, tetragonal and hexagonal [5].

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FEM involves the subsequent for the resolution a boundary price problem:
(i)Discretization of the domain (ii) Derivation of the component equations (iii) Assembly of the weather (iv) Solutions of the system equations.

The field analysis victimization FEM has 3 steps
(i) Preprocessing stage (ii). Processor stage (iii). Postprocessor stage

III. BASIC MATHMETICAL FORMULAS

Utilized in magnetic attraction FIELD -In field of force numbers of quantities area unit used. They're reticular with one another. Magnetic flux (ø) in field of force is extremely kind of like current (I) in force field. Magnetic flux is said with field of force density (B) as

$$Ø = B.A \qquad (1)$$

Here A is that the space of the magnetic flux path. Magnetic flux is Weber and therefore the unit of field of force density is Weber/m². Magnetic flux will be calculated with magneto-motive force (F) and reluctance(R) of the trail. $F=NI$ (2)
Where N is that the No. of turns used and I, is the current flow through the coil. Then

$$Ø = F/R \qquad (3)$$

Using equation (2) equation (3) will be diagrammatic

$$Ø = NI/R \qquad (4)$$

Reluctance of the magnetic path is depends on length of the magnetic path (l), porosity of magnetic material (μ) and space of flux flowing path. $R = l/\mu A$ (5)

Magneto-motive force (F) in magnetic circuit is comparable to EMF (E) in electrical device. Field of force density (B) is comparable to force field density (D).Maxwell's equations represent one among the foremost elegant and summary thanks to justify the basics of the electricity and magnetism. With the assistance of Maxwell's equations one will develop most of the operating relationship in static or time varied magnetic attraction field. The differential for of Maxwell's equations for the time varied condition is given below.
(1) $\nabla .D = \rho v$ (2). $\nabla .B = 0$ (3). $\nabla X E = -dB/dt$ (4). $\nabla X H = J + dD/dt$

A. **Basics of motor structure specification**
Torque (T) generated by BLDC motor is depends on rotor diameter (D) and axial length of the rotor (L) .It will be diagrammatic as $T = KD^2L$ (6)

With equation (6) it will be understood that the torsion generated by a motor is especially depends on diameter of rotor. Because the diameter of rotor will increase circumference space accessibility for static magnet will increase. It can be Interpreted that if the axial length is double, torsion will double at constant power [3,4].Cogging torsion is outlined because the unwanted torsion that's made within the PM BLDC motor thanks to the interaction of the rotor magnets and slots and poles of the machine. The cogging torsion reduces the typical torsion made by the machine and introduces unwanted torsion ripple within the PM BLDC motor. The expression for the cogging torsion is given by $T_{cog} = -½ Ø_g^2 dR/Dɵ$ (7)

Where $Ø_g$ is that the air gap flux and dR/dϴ is that the amendment in air gap reluctance with respect rotor angle.
It's vital to notice that almost all techniques wont to scale back the cogging torsion can scale back the effective back electromotive force and thence the ensuing mutual torsion production.

B. Motor style: The basic style of the motor is finished in RMxperttm of Ansys Maxwell and Finite component methodology has been exhausted Maxwell 2nd. Parameters given within the table area unit used as an input to the computer code.

a) **MatLab** - It offers varied machine-specific, template- primarily based interface for induction, synchronous and electronically and brush commutated machines. These templates permit to simply enter style parameters and to judge style trade- offs early within the method. Crucial performance knowledge like torsion versus speed, power loss, and flux within the air gap, power issue and potency will be quickly calculated. The model designed in Matlab will be simply exported in Maxwell project (2D/3D) for Finite component methodology and magnetic attraction transient analysis.

b) **Stator design**- stator coil is that the static a part of any motor or generator. Table-1 shows the parameters of study setup for style. On the idea of table one parameters the stator coil knowledge are going to be mentioned in table-2 [6].

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Table -1

SR. NO.	PARAMETER	VALUE
1	Rated power(W)	2000
2	Rated voltage(Volt)	110
3	Rated speed(RPM)	3000
4	No. of poles	4
5	Frictional loss(W)	10
6	Windage loss(W)	2

Table -2

SR. NO.	PARAMETER	VALUE
1	Number of slot	12
2	Outer Diameter(mm)	120
3	Inner Diameter(mm)	62
4	Length of stator core(mm)	55
5	Number of slot	12
6	Stacking factor	95

Stator in Figure one is built with the assistance of table 2.

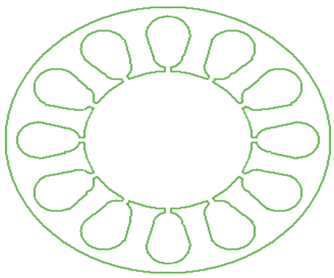

Fig.1. stator coil pure mathematics

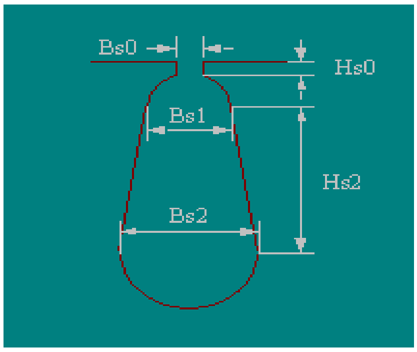

Fig.2.Slot Dimension

c) **Slot parameters**- form and dimensions of the slot area unit mentioned in figure two and table three

Table -3 Slot Dimension

SR. NO.	PARAMETER	VALUE
1	Hs_0(mm)	1.8
2	Hs_2(mm)	9.6
3	Bs_0(mm)	2.7
4	Bs_1(mm)	11.60
5	Bs_2(mm)	18.80

d) **Rotor design**- it's the moving element of the magnetic attraction system within the motor or generator. For the rotor static magnet pole several shapes area unit given in RMxprt however the given figure three is taken.

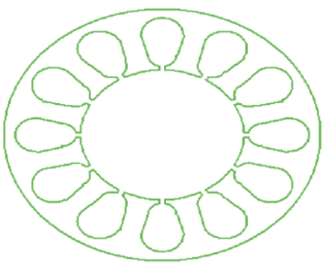

Fig.3. Rotor pure mathematics

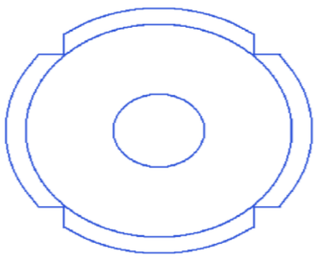

Figure 4 cross-sectional read of BLDC motor

IJARCCE
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Table -4

SR. NO.	PARAMETER	VALUE
1	Minimum Air gap(mm)	1
2	Inner Diameter(mm)	20
3	Outer Diameter(mm)	62
4	Length of rotor (mm)	57
5	Types of steel	Steel 1008
6	Embrace	0.90
7	Thickness of magnet (mm)	5
8	Magnet type	NdFe35
9	Width of magnet (mm)	38.70

Table -5 Alternative vital parameter for motor

SR. NO.	PARAMETER	VALUE
1	Residual Flux Density(Tesla)	1.50
2	Coercive Force(A/m)	900000
3	Maximum Energy Density (kj/m^3)	275.68
4	Average Input Current(A)	16.09
5	RMS Armature current(A)	16.09
6	Armature (Current Density(A/mm^2)	0.57
7	Frictional and Windage Loss(W)	10.68
8	Iron core Loss(W)	0.0022
9	Armature Copper Loss(W)	10.58
10	Transistor Loss(W)	69.70
11	Diode Loss(W)	5.69
12	Total Loss(W)	97.50
13	Output Power(W)	1899.50

Some vital plots ore given below once the simulation of the model was dead within the Matlab.

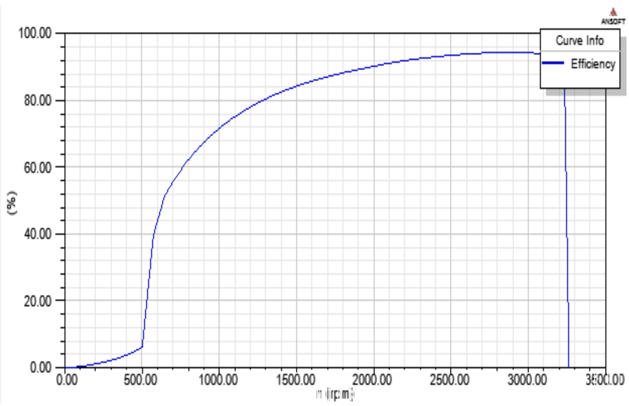

Fig.5. potency vs speed

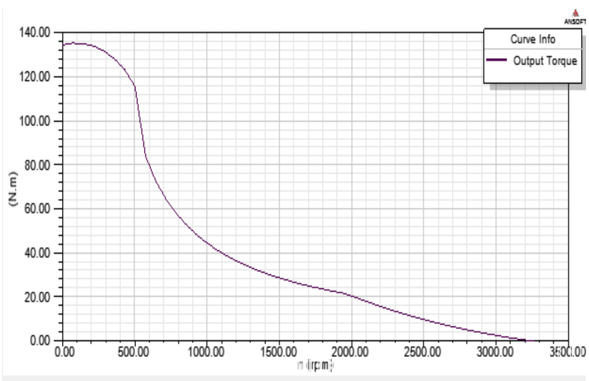

Fig.6.Torque vs Speed

IJARCCE

ISSN (Online) 2278-1021
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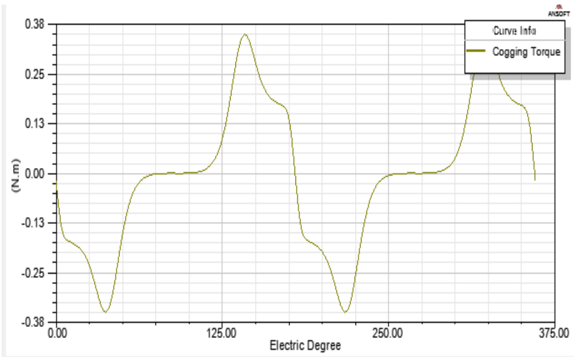


Fig.7. Cogging torsion vs electrical Degree

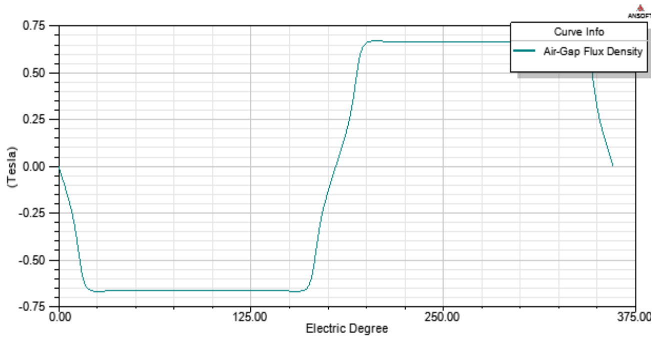


Fig.8. Air Gap concentration vs electrical Degree

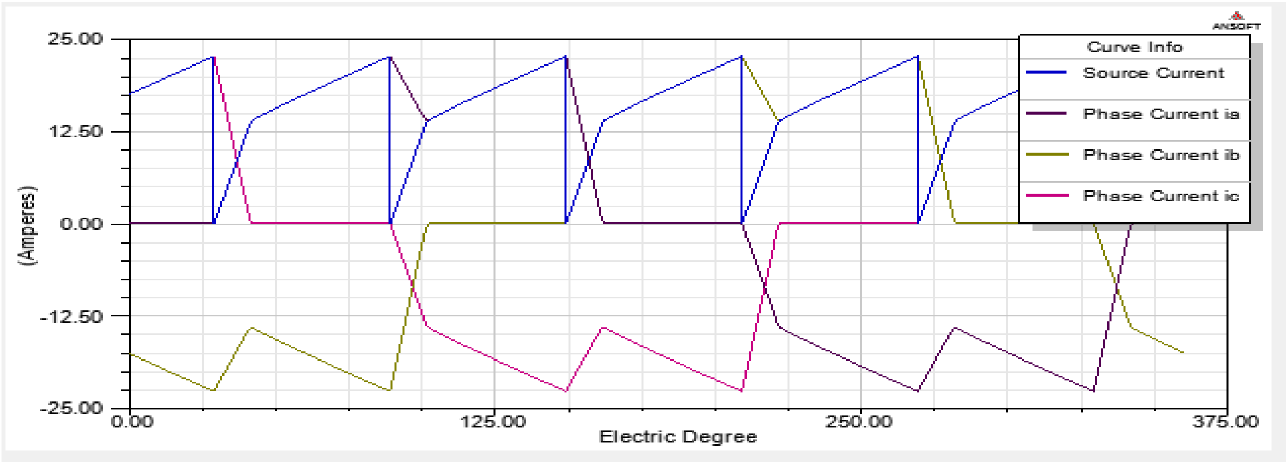
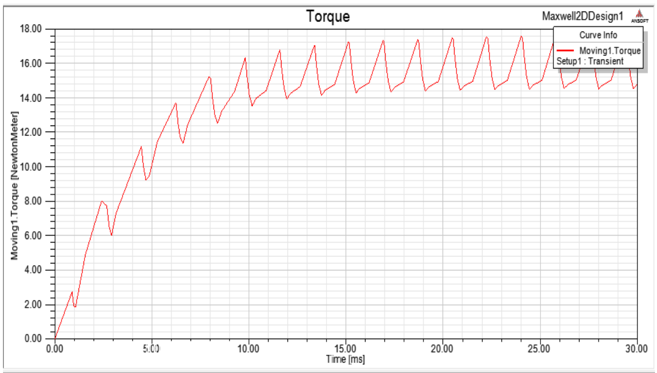


Fig.9. Winding Current below load vs electrical degree

V. ANALYSIS ONCE INCREASING LEAD ANGLE OF MANAGEMENT CIRCUIT-

Higher than motor coming up with is finished once lead angle is taken zero degree. For up motor performance lead angle is varied and therefore the amendment in motor performance is analysed. Once dynamic motor lead angle potency of motor is accumulated. Lead angle shows however early the section voltage is injected. Once lead angle will increase, section current excites the sooner winding. As every section current has an equivalent phase as every section back electromotive force, the PMBLDC motor offers the given torsion demand whereas needing a lower demand current and achieves higher potency as copper loss is reduced. Table six shows some vital parameter once lead angle is varied from zero degree to thirty degree. On lead angle thirty degree the torsion made by motor is shown in Fig.9 & Fig. 10



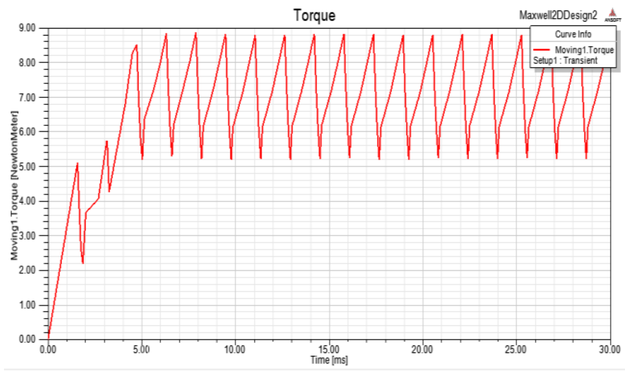


Fig.9. Motor torsion at zero degree lead angle

Fig.10. Motor torsion at thirty degree lead angle

ISSN (Online) 2278-1021
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Table -6

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3	Maximum Energy Density(kj/m^3)	275.68
4	Average Input Current(A)	16.09
5	RMS Armature current(A)	16.09
6	Armature (Current Density(A/mm^2)	0.57
7	Frictional and Windage Loss(W)	10.68
8	Iron core Loss(W)	0.0022
9	Armature Copper Loss(W)	10.58
10	Transistor Loss(W)	69.70
11	Diode Loss(W)	5.69
12	Total Loss(W)	97.50
13	Output Power(W)	1899.50
14	Input Power(W)	1997.50
15	Efficiency	95.09
16	Rated Speed(RPM)	3189
17	Rated Torque(N-m)	5.69
18	Maximum Output Power(W)	7390.59
19	Air Gap Ampere Turn(A.T)	579.59
20	Magnet Ampere Turn(A.T)	-1259.20

VI. CONCLUSION

This paper represents the fundamental style plan of Permanent Brushless DC Motor. 1st of all basics of magnetic circuit is justify then needed basic equation utilized in magnetic attraction field is describes. During this paper Permanent BLDC motor utilized in star vehicle of 2000W and 3000 rate is style. This paper shows that motor offers significantly smart potency at rated torsion and at rated speed. Motor is style in RMxprt and therefore its magnetic attraction field analysis is finished on Maxwell 2nd. Once coming up with of motor, analysis is finished by varied the lead angle of negative feedback circuit. It's seen that once the lead angle is accumulated from zero degree to thirty degree potency of the Permanent BLDC Motor is accumulated. By increasing lead angle rated speed of motor is accumulated. Increase in potency is achieved at the price of decrease in rated torsion and increase in ripple in torsion.

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