International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 317-321 www.ijaem.net ISSN: 2395-5252

Simulation of Brushless DC motor

Dr. D. B. Hulwan[1], Prasad Mane[2], Manasi Mogal[3], Om Nevkar[4], Om Kanade[5], Onkar Wadtile[6], Rohit Paikrao[7]

[1] *Head of the Dept, Mechanical Engineering Department, Vishwakarma Institute of Technology Pune, India*
[2,3,4,5,6,7] *Students Mechanical Engineering Department, Vishwakarma Institute of Technology Pune, India*

Date of Submission: 25-02-2023 Date of Acceptance: 05-03-2023

ABSTRACT - Permanent magnet motors are another name for brushless direct current (BLDC) motors. Due to their superior performance effect, dependability, and easy of control, it is used in many electric cars. The difficulty of carrying out necessary for control orders has been addressed by a new generation of micro-controllers and most recent electronics, making motor more useful for a variety of tasks. Using Ansys Maxwell and MATLAB Simulink, the paper's primary goal is to simulate a brushless DC motor used in an electric scooter.

Key Words: Brushless DC motor, electric scooter, Ansys Maxwell, MATLAB SIMULINK.

I. INTRODUCTION

Because BLDC motors are more affordable and easier to build than conventional AC motors, they are frequently utilized for variable speed control in AC motor drives. In comparison to brushed motors, they are more capable and react quickly and aggressively. They also integrate superior torque into the motor, making them useful in applications where weight and space are key considerations. For high control concentration design approaches, Brushless Direct current motors are appropriate. Due of their tight temperament, Brushless Direct current motors are the most favored motors for use in electrical vehicles.

BLDC motors can also be classified into two categories:

1.1 Out-runner type Brushless Direct Current motor:

A form of brushless DC motor known as a "out-runner" BLDC motor revolves around the motor's axis while being positioned externally to the stator. Due to the wide diameter rotor produced by this kind of motor design, the performance of the motor is improved for high-load applications and its torque output is increased.

Out-runner BLDC motors are frequently employed in devices including industrial drives, drones, and electric bicycles. Compared to other types of motors, they have benefits including a high torque density, high efficiency, low noise, and great dependability. Due to the lack of a gear system, this motor makes the entire vehicle lighter. Additionally, it eliminates the area needed for rising the motor.
Manufacturers of electric vehicles including Tronx, Hullical, Spero, and others often choose the motor. Producers of two-wheelers also employ it.

1.2 In-runner type Brushless Direct Current Motor:

Similar to conventional motors, the rotor of this sort of motor starts inside, while the stator faces outward. Due to its efficiency and speed, Brushless motors are widely employed in high-speed devices like fans and power tools. However, compared to out-runner type Brushless Direct Current motors often produce less torque.
Because these motors need an external transmission arrangement to transfer power to the wheels, the outrunner layout is less cumbersome. BLDC motors are widely used by three-wheeler manufacturers. Producers of low and medium speed vehicles also employ BLDC motors for Actuation.

This paper confers a Brushless Direct Current Motor with the trapezoidal and curve form (sinusoidal) back-EMF wave form. Figure.1 under displays conventional block diagram of BLDC motor controls.

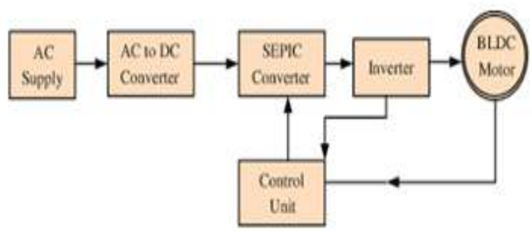


Figure 1- Block figure of Brushless Direct current motor

Energy converter, restraint data algorithm, and brushless direct current motor control essential block diagram. The (PMSM)motors, which changes electric energy to machine-driven energy, receives energy from the source through the inverter. Rotor position sensors

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 317-321 www.ijaem.net ISSN: 2395-5252

are present in a brushless direct current motor. The command administrator, which may be classified as torque, speed command, voltage, etc., is in charge of keeping order. The configuration of the data control algorithms, which include the two main types of voltage source and current source-based drives, determines the type of the Brushless Direct Current motor.

II. BLDC MOTOR CALCULATIONS:

For simulation and calculations, parameters of Ather 450 were considered Ather 450 Specifications
Ather attains a speediness of 11.11 m/sec in 3.9 seconds.

Maximum acceleration = $\frac{(11.11-0)}{3.9}$

Motor Power (Continuous / Peak)	4 kW / 6 kW
Top speediness	80 km/hour
Acceleration (0 – 40kmph)	3.9 sec
Gradeability	7 Degrees
Motor type	BLDC
Battery type	Lithium – ion
Nominal voltage	51.1 V
Kerb Weight	111 kg
Transmission category	Belt Drive
Transmission ratio	7: 8: 1
Tire Diameter	12 inches

Motor torque and speed calculations following forces are considered for calculating the required torque output.

1.Rolling Resistance
Let the mass of the driver be 80 kg.
Hence total mass (m) = Kerb mass + driver mass
=111 + 80 = 191 kg
Rolling resistance = μ*m*g
= 0.015 * 191 * 9.8
= 28 N

2.Acceleration force = 58.2 N
3.Gradeability
The average gradeability of Indian roads is around 7 degrees. Gradeability force = m*g*sin 7
= 191 * 9.8 * sin 7
= 206 N
Total resistive force = 28 + 542 + 58.2 + 206 = 834.2 N

= 2.84 m/s2 Acceleration force = m * a
= 542 N

4.Aerodynamic drag
For aerodynamic force, the frontal area, the drag coefficient and the velocity of the vehicle have to be considered. Frontal Area (A) = 0.875 m2

Drag coefficient (C) = 0.22

Maximum speed = 80 kilo-meter/hour = 22.22 meter/sec

Air Resistance = ½* ρ* A* C* (V)2
= ½ * 1.225 * 0.875 * 0.22 * (22.22)2

Torque required to overcome this force = 834.2 * tire radius = 127.13 N m

Torque to be supplied by motor = 127.13 / Transmission Ratio = 16.3 N m

Considering transmission efficiency to be 85% Torque to be supplied by motor = 16.3 * (100/85)
= 19.2 Nm

Motor speed calculations -:
Maximum velocity of the vehicle = 22.22 m/sMaximum angular velocity of the tires = v / r
= 22.22 / 0.1524
= 145.8 rad/s = 1393 RPM
Maximum angular velocity of the motor = angular velocity of the tires * transmission ratio
= 1393 * 7.8
= 10,865 RPM

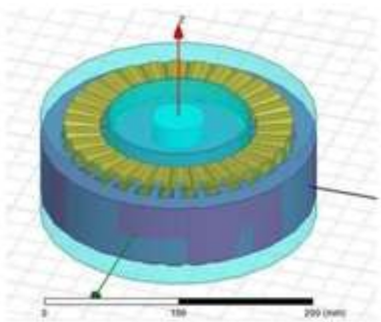


Figure 2: Simulation 3D prototypical

Simulation Input Data-:

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 317-321 www.ijaem.net ISSN: 2395-5252

Rated Output power	4.5 kW
Rated Voltage	51.1 V
Rated Speed	3000 RPM
No of poles	4
Frictional loss	10 W
Windage loss	20 W

Simulation Results-:

No load speed	3495 RPM
Average Input Current	107.322 A
Root means square input current	109.169 A
Total power loss	983 W
Output power	4500 W
Input power	5484 W
Efficiency	82%
Rated Speed	2456 RPM
Rated Torque	17.5 Nm

III. SIMULINK MODEL:

The (Brushless Direct Current) motor is also simulated in MATLAB Simulink.

3.1 MATHEMATICAL MODELLING:

This article models a three-phase, four-pole brushless direct current motor. The main difference between a synchronal mechanism with a permanent magnet rotor and a brushless direct current motor is the construction of the rotor, which alters the machine's dynamic peculiarities. The motor is likewise powered by a 3- phase power source. The following are the modelled equations for the armature winding.: -

RIa = VA- $L\ dIa/dt$
RIb= VB - L dIb/dt
RIc= VC - L dIc/dt

Name	Represented
Armature	Eo
Voltage	V
Current	A

Back-Emf of each stage has a phase variance of 120 electric grades & back- Emf and rotor location are linked via some meaning.
Calculation of each stage for back-Emf is as follows: -
$ea/\ \omega =(\theta e)$
$eb+2\pi/3 = \theta e$
$ec=(\theta e+2\pi/3)$

Where Kw - back-Emf continual of one stage (V per rads-1)
θe- rotor angle in electric degree ω- rotor speed (rad. S-1)
Rotor angle electrical (θe) and Rotor angle mechanical 90m are linked as: -

$$\theta e = P/2\theta m$$

Where P is the no of ends on rotor
Therefore, the total electromagnetic force Te in N-M can be uttered as follows: -
$Te\times\ \omega = (eaia+ebib+ecic)$

The machine-driven force transferred to the motorized shaft: -

$$Te = (Jdw/dt+ B\omega)+ Tl$$

Where Tl = weight force [N-M] J= inertia of rotor shaft [Kgm2]
B = friction constant [Nms.rads-1]

The illustration for Simulink model is revealed in figure 3&4 below-

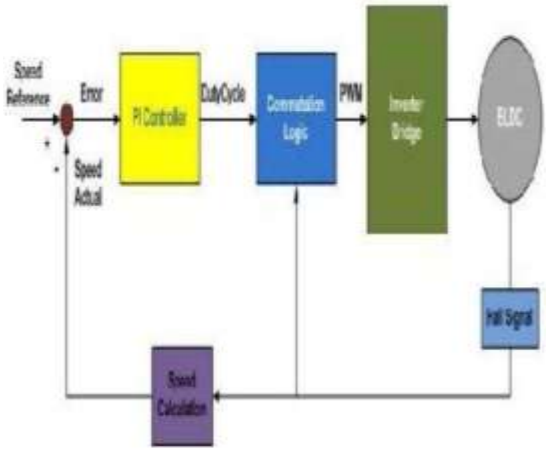


Figure 3: Block diagram for Simulink prototypical

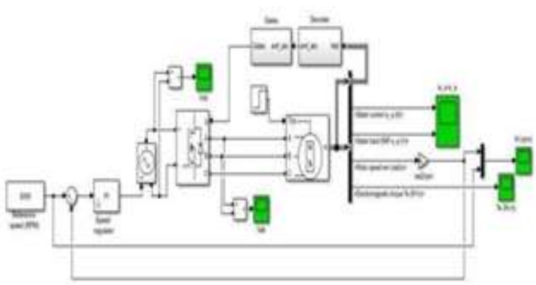


Figure 4: Simulink model

The Brushless Direct current motor is simulated in MATLAB Simulink using a closed loop PI controller. The motor is powered using a 6-phase inverter.

The constraints are as follows

Number of phases	3
Back emf wave form	Trapezoidal
Stator stage resistance	2.8750 ohm
Stator stage induction	8.5×10^{-3}
Flux connection	0.175
Torque continual	1.4
Back emf flat zone	120 degrees
Inertia	$0.8*10^{-3}$

3.2 Model description:

Simulated outcomes from the design thinking mentioned above have been calculated and displayed. The torque trouble is delivered at 0.01 seconds after the speediness is set at 10,000 rpm, and the speed guideline is completed at that speed. The simulation waveform depicts the back Emf & stator coil waveforms and reveals that the back Emf, phase voltage, and stator current are all luxated by 120 degrees. The back Emf and stator waveforms are also quasi sinusoidal in character.

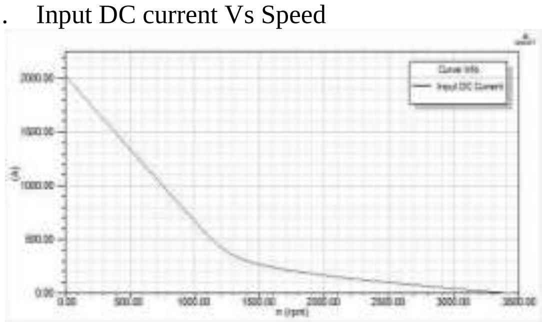
3.3 Working:

For inverter assembly, reference speed block takes feedback from output of Brushless Direct Current motor from output speed. This generates error signal and is processed by PI controller and generates corresponding output. Based on that corresponding output, 6 pulse inverter generates pulses which controls speed of Brushless Direct Current motor.

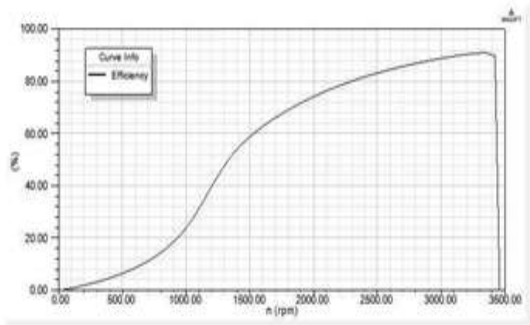
To control gate impulse of inverter it is necessary to sense stator position of (BLDC) motor. This is done using hall sensor. Hall instrument gives a feedback emf and according to that we provide switching pattern for inverter. These switching patterns are given through gates block.

IV. RESULTS:

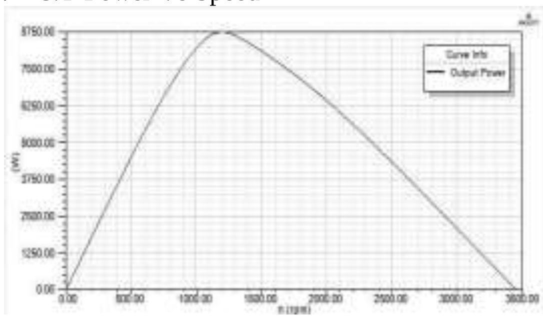
1. Input DC current Vs Speed



2. Efficiency Vs Speed

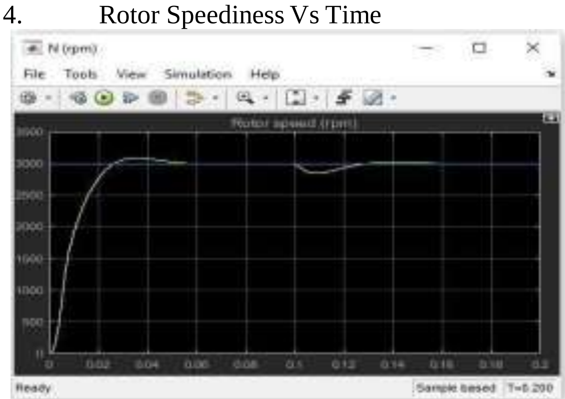


3. O/P Power Vs Speed

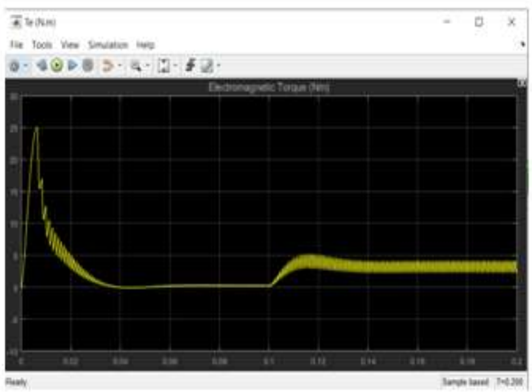


The rotor speed becomes constant with value of referencespeed of 3000 rpm after some time.

4. Rotor Speediness Vs Time

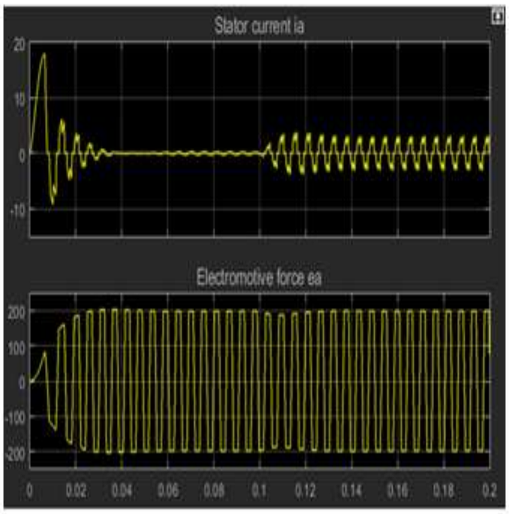


5. Electromagnetic force vs time



International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 317-321 www.ijaem.net ISSN: 2395-5252

6. Stator Current vs Time and Electromotive Power vs Time



V. CONCLUSIONS

The simulation of BLDC motor used in Ather two- wheeler was done in Ansys Maxwell. The simulation gave an insight on the efficiency, current and output power of the motor. Furthermore, speediness controller of Brushless Direct Current motor was done on MATLAB Simulink software.

REFERENCES

[1] F. Rodriguez and A. Emadi, ―A novel digital controltechnique for brushless DC motor drives,‖ IEEE Transaction Industrial Electronics., vol. 54, no. 5, pp.2365–2373, Oct. 2007C.

[2] Gencer and M. Gedikpinar," Modelling and Simulation of BLDC Motor Using MATLAB/SIMULINK", Journal of Applied Sciences, vol. 6, issue 3, pp. 688-691, 2006

[3] Cai, C., Zhang, H., Liu, J., & Gao, Y. (2010, March). Modeling and simulation of BLDC motor in electric power steering. In 2010 Asia-Pacific Power and Energy Engineering Conference (pp. 1-4). IEEE.

[4] Prasad, G., Ramya, N. S., Prasad, P. V. N., & Das, G. T. R. (2012). Modelling and Simulation Analysis of the Brushless DC Motor by using MATLAB. International journal of innovative technology and exploring engineering (IJITEE), 1(5), 27-31.

[5] Pal, P., Shubhum, T. M., & Ojha, A. (2014). Simulation of brushless dc motor for performance analysis using MATLAB/SIMULINK environment. International Journal on Recent and Innovation Trends in Computing

[6] Zafar, Z. U. A., Ali, N., & Tunç, C. (2021). Mathematical modeling and analysis of fractional- order brushless DC motor. Advances in Difference Equations, 2021, 1-25.

[7] Rao, A. P. C., Obulesh, Y. P., & Babu, C. S. (2012).Mathematical modeling of BLDC motor with closed loop speed control using PID controller under various loading conditions. arpn journal ofengineering and applied sciences, 7(10), 1321-1328.

[8] Tsai, M. F., Quy, T. P., Wu, B. F., & Tseng, C. S. (2011, June). Model construction and verification of a BLDC motor using MATLAB/SIMULINK and FPGA control. In 2011 6th IEEE Conference on Industrial Electronics and Applications (pp. 1797- 1802). IEEE.

[9] Dudhe, S. S., & Thosar, A. G. (2014). Mathematicalmodelling and simulation of three phase bldc motor using matlab/Simulink. International Journal of Advances in Engineering & Technology, 7(5), 1426.