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DESIGNING, MODELLING AND SIMULATION OF A SIX-SEATER ELECTRIC VEHICLE USING PMSM MOTOR AND LFP BATTERY

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Abstract

This paper presents the designing, modelling, simulation, and analysis of a 6-seater electric vehicle. The mainaim of this paper is to design a vehicle that works efficiently in the EV sector. SOLIDWORKS software was used for designing the model of the vehicle. To check the feasibility of the frame design, finite element analysis has been done using ANSYS 2021R2 software and for electrical components, the designing, modelling, and simulation were done using MATLABR2021b. PMSM motor was selected, for controlling the speed of the vehicle sine wave operated Controller was usedwith a supply battery pack of Lithium Ferro Phosphate. The vehicle has a transmission system containing a Differential with a double gear system with actuated hydraulic brakes connected to the electrical components. A proper and efficient market survey was done on the chassis material, brakes, motor, battery, transmission,and other small components to manufacture our vehicle.

Keywords: Solidworks, aisi1018, ANSYS, matlab2021b, PMSM, sine wavecontroller, lithium ferro phosphate.

1. Introduction

Electric vehicles are started getting popularity because of their efficient working, that they not only reduce noise and pollution, but also reduces the dependency of transportation on fuels providing that the power generated in the vehicles is from battery other than fuels. The current scenario is encouraging ecofriendly vehicles to minimize the damage occurred by the emission. EV's can also be used in reducing carbon emissions. And most of the maintenance cost associated with I.C engine are eliminated. Production of zero release of CO_2 requires the energy of the EV's which is basically produced from non-fossil fuel sources such as alternating energies. EV's are normally associated with benefits to the environment and atmosphere. These benefits include reduction of local pollution from the vehicle itself by reducing the dependence on oil and other fossil fuels and carbon emission. A wide range of engine vehicles were in trend since the mid of the 20^{th} century.

Our Electric vehicle is specially designed for climbing a gradient of 15º. The best alternative for the engine isthe electric motor which in comparison can give the same output power. Basically, motor replaces engine andtherefore the vehicle gets modified in both the design and performance. The vehicle then runs only on the electricity and is designed for the necessary requirements for the vehicle.

2. PMSM MOTOR AND IT'S CONTROLLING

Formulae used: - Torque (Nm) = $9.5488 * power\ (kw) / 60$

S.no	Motor Speed(rpm)	Motor Torque (Nm)
1.	500	95.049
2	1000	47.74
3	1500	31.83
4	2000	23.87
5	2500	19.10
6	3000	15.91
7	3500	13.64
8	4000	11.94
9	4500	10.61

Table 1: - Calculated Motor Ratings

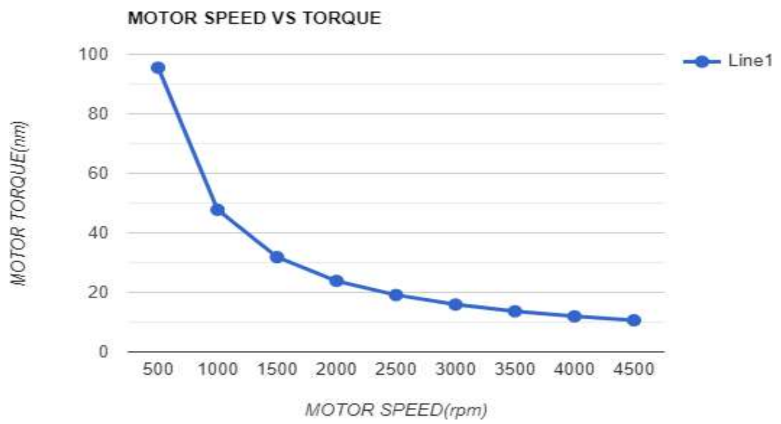

Fig.1: - Speed vs Torque Graphs

$$\text{Linear velocity} = \frac{\text{rpm of wheel} * \text{circumference of tyre}}{60} \qquad \text{Eq. (2)}$$

$$Velocity = linear\ velocity\ (m/sec) * 3.6 \qquad \text{Eq. (3)}$$

S.NO	ANGULARVELOCITY (RAD/SEC)	LINEAR VELOCITY(M/S)	VELOCITY (KM/H)
1.	4.950	1.257	4.525
2.	9.897	2.514	9.050
3.	14.846	3.771	13.575
4.	19.496	5.028	18.101
5.	24.745	6.285	22.626
6.	29.694	7.542	27.151
7.	34.643	8.799	31.677
8.	39.592	10.056	36.202
9.	44.540	11.313	40.727

Table 2: - Motor Calculations-2

S.no	parameter	values
1.	Transaxle ratio	10.5
2.	Rolling resistance	17 N
3.	Drag resistance	12.20 N
4.	Gradient resistance	258.81N
5.	Torque required at wheel	163.87N/m
6.	Total resistance	288.02N

Table3: - Traction Calculations

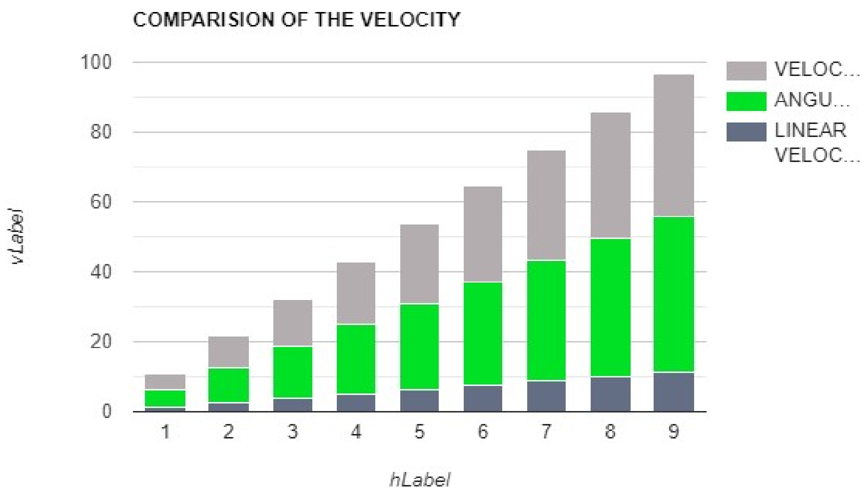

Fig.2: Comparison of Velocities

3. CONTROLLER

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A Motor Controller is a device of group of devices which coordinates the performance of the electric motor. On the basis of motor, we have chosen sine wave oriented with CAN communication with the following specifications:

S.No.	PARAMETERS	VALUES
1.	Voltage	72v/60v
2.	Upper cut-off voltage	78v/65v
3.	Lower cut-off voltage	66v/56v
4.	Continuous current	150Amp
5.	Peak current	200Amp
6.	Peak power	10kw
7.	Current with no load	3A
8.	Efficiency	89%
9.	Brand	CY GOLD

Table 4: -Specification of 60v/72v Controller

4. BATTERY

We are going with the lithium ferrous phosphate or LFP battery of rating 72v 100Ah. It is a type of lithium-ion battery that uses lithium iron phosphate ($LiFePO_4$) on the cathode and graphitic carbon electrode with the metallic backing at the anode terminal.We are using this battery because it is cheaper, efficient, less toxic, has long cycle life and many other technical factors. The battery we have chosen also consists of the CAN Communication, which gives us the overall battery parameter.

S.NO	PARAMETER	VALUES
1.	Specific energy	83wh/kg
2.	Energy density	310wh/l
3.	Specific power	119wh/kg
4.	Cycle durability	2000 at 70% soc
5.	Cycle life	1800-2000
6.	Nominal voltage	72v
7.	Nominal capacity	100Ah
8.	Max discharge current	300A
9.	Discharge cut off	2.5V
10.	Charge current	100A
11.	Charge cut-off	3.65V
12.	Nominal voltage per cell	3.2V
13.	Discharging rate	5c
14.	Module dimension	404x410x285
15.	Charge rate	3c

Table5: -Specifications of battery

5. CHASSIS

Chassis is the foundation structure of any vehicle that supports it from underneath. The purpose of the chassisis to bear the weight of the vehicle in it's ideal and dynamic states. We have designed the space frame chassisby using different types of square and rectangular pipes.

Table6: -

S.NO	PROPERTIES	AISI 1080
1.	Density	7.7-8.03 g/cm^3
2.	Tensile strength	615.4Mpa
3.	Yield strength	375.8 Mpa
4.	Young's modulus	190-210 Gpa
5.	Shear modulus	80 Gpa
6.	Poisson's ratio	0.27-0.30

Specification of Chassis Material

Fig1: - Chassis Design

6. STEERING SYSTEM

The steering system works on the steerable wheels which are the front wheels of the vehicles that changes thedirection of the moving vehicle. We are using "Rack n Pinion" type of the steering system which is a manual steering system.

S.NO	COMPONENTS
1.	Steering system
2.	Steering column
3.	Steering shaft
4.	Steering gear
5.	Steering gear
6.	Steering linkage
7.	Wheels

Table7: -Components of steering system

6.1 RACK AND PINION

In this type of the steering gear, a pinion is mounted at the end of the steering shaft which engages with the Rack provided with the ball joints on each end which allows it for the rise and fall of the wheels. The rotatingmovement of the steering wheels makes the Rack in the motion. This type of steering gear gives enough lowgear reduction for the vehicles and also is suitable for heavy motor vehicle.

Fig5: - Rack and Pinion Steering System

7. BRAKING SYSTEM

Brakes are the mechanical devices that are used in the retarding motion of the vehicle. Brakes are also usedto stop the vehicle rapidly within a small distance. These are also used in holding the vehicle in rest position

even on the inclined road against the pull of gravity. We are using two types of brake systems in our vehicles:

1. Disc Brake system (used in front-wheel)
2. Drum Brake system (used in Rear wheels)

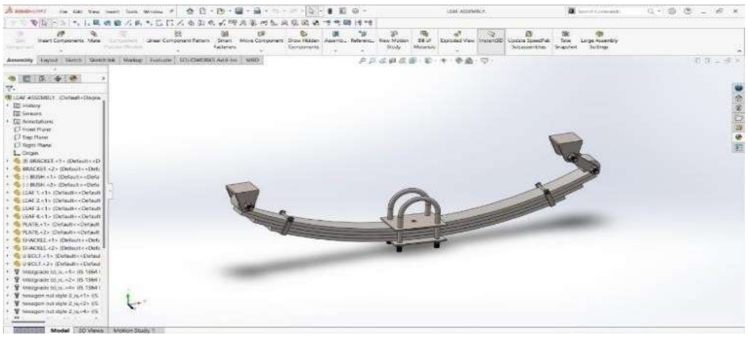
8. SUSPENSION SYSTEM

The function of the suspension is to isolate the vehicle from shocks and vibrations generated by the roadsurface, suspension providing stability to the vehicles.

8.1 FRONT AND REAR SUSPENSION

The suspension used in front wheel for our vehicle is Leaf spring suspension which ithe most commonsuspension used in the Automotive vehicles.

Fig6: - Leaf Spring Suspension



9. WHEELS AND TYRES

The wheels and the tires of the vehicles are to support the weight of the vehicle. The wheels should have wellbalanced construction especially for running at high speeds. The control acceleration and braking take place by the tires and their proximity on the old surface. The tires should be large enough to bear the load of the vehicle on the road.

WHEEL DIMENSIONS

The dimensions of the

wheel 145/70R12.

Where,

- Width = 145mm
- Aspect ratio = 70)
- Diameter of tire = 20" (inch)

10. Results: Software - ANSYS

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Front static analysis

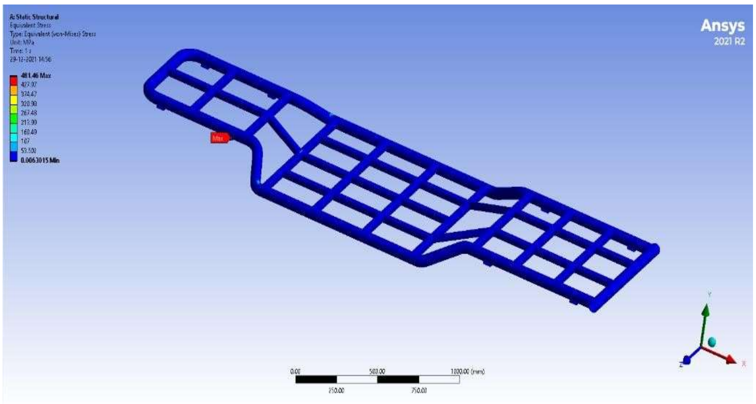

Fig10: -Factor of safety

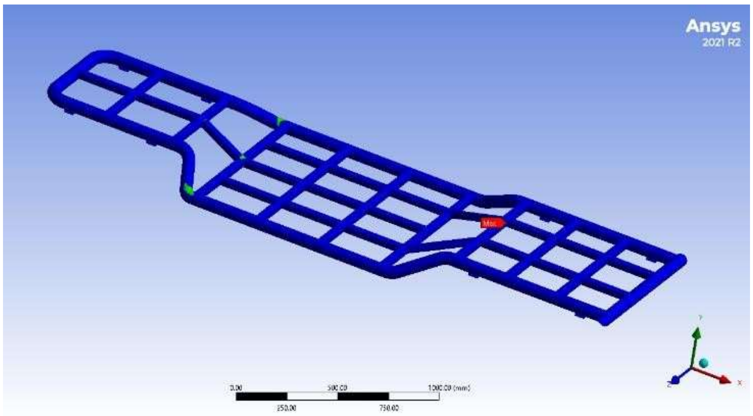

Fig11: - Total deformation

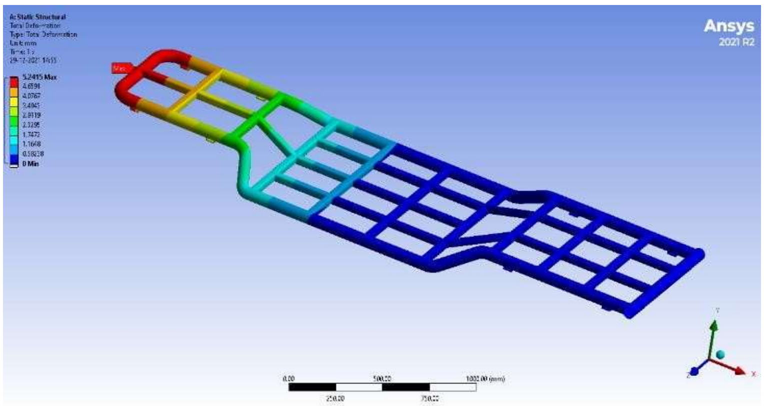

Fig12: - Equivalent stress

11. MATLAB: - MODELLING AND SIMULATION

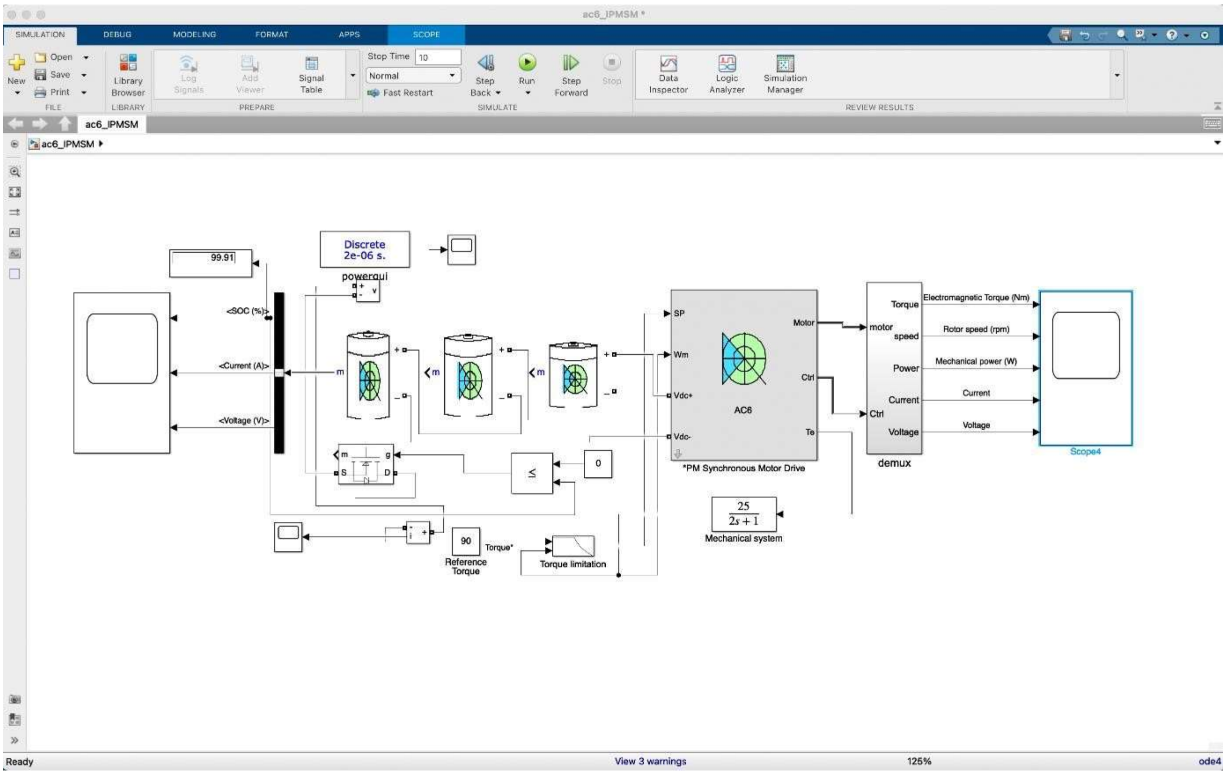

Fig13: - MATLAB simulation

The above figure is the MATLAB modelling of the electrical circuit for our electric vehicle. In this circuit, we have used a battery pack of 72V 100 Ah in which the all connection is made in series combination taking nominal voltage of 24V in each cell and capacity of 100 Ah. We have done modelling using PMSM drive.

S.NO	GRAPHS	TORQUE	CURRENT
1.	GRAPH(a)	90Nm	174.2A
2.	GRAPH(b)	120Nm	228.7A
3.	GRAPH(c)	130Nm	246.2A
4.	GRAPH(d)	140Nm	263.3A
5.	GRAPH(e)	150Nm	279.9A
6.	GRAPH(f)	160Nm	296A

Table8: - Tested data of Motor in Simulink

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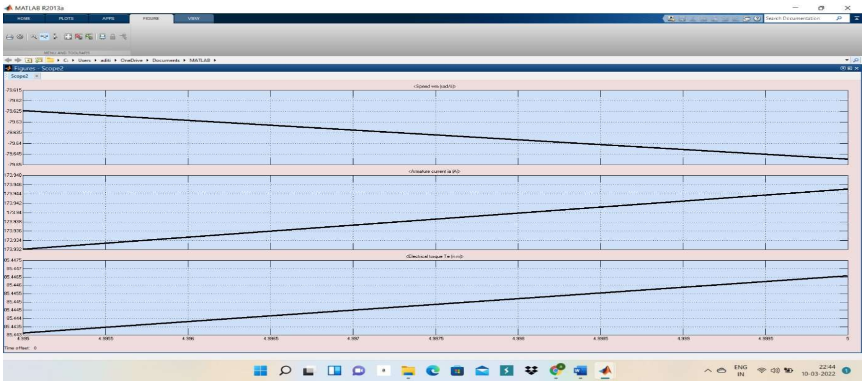
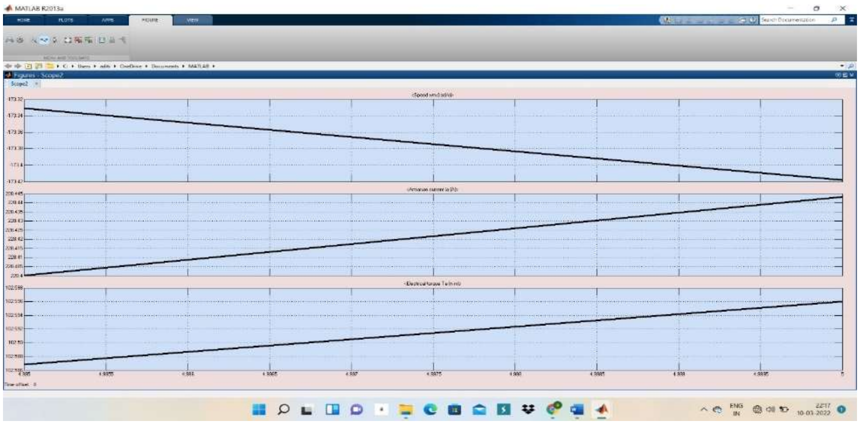
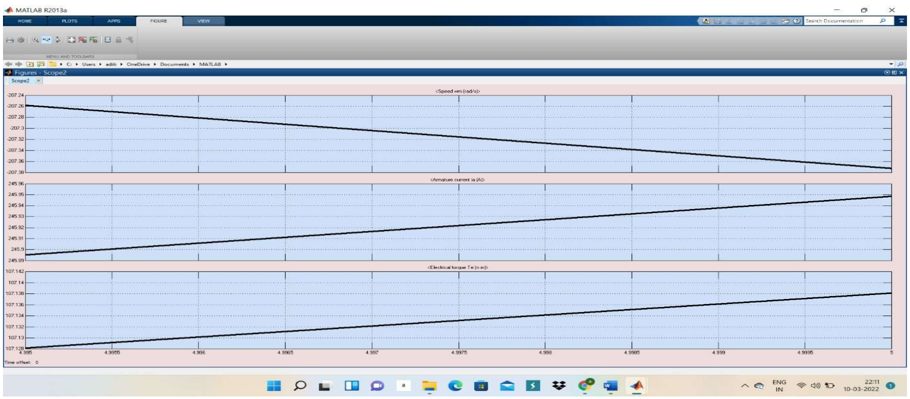


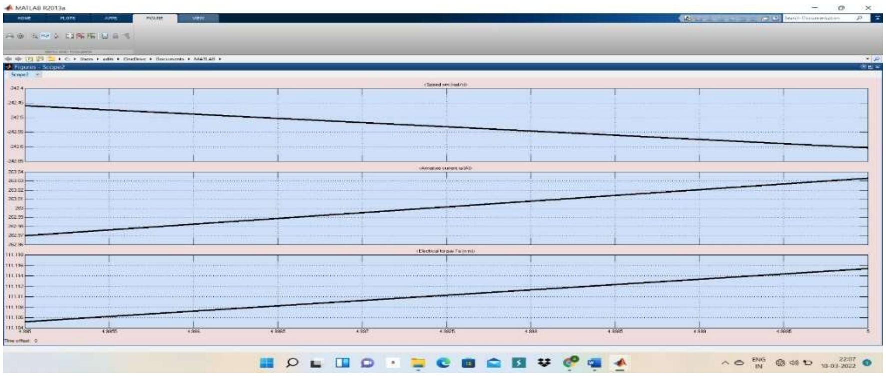
Graph (a)



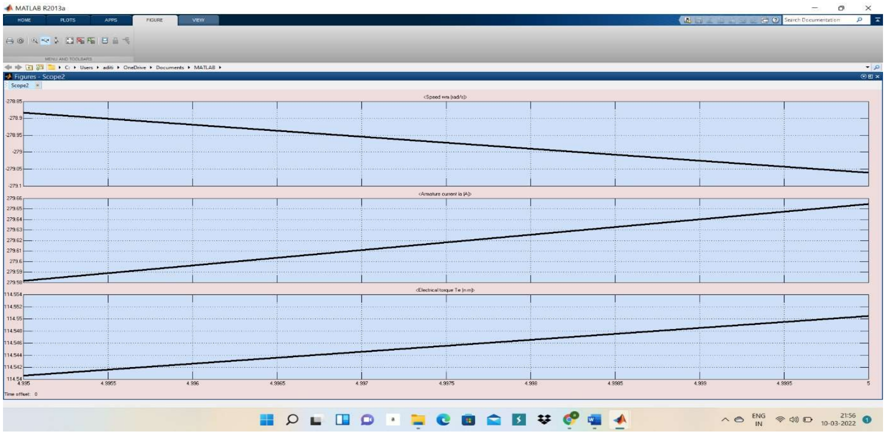
Graph(b)



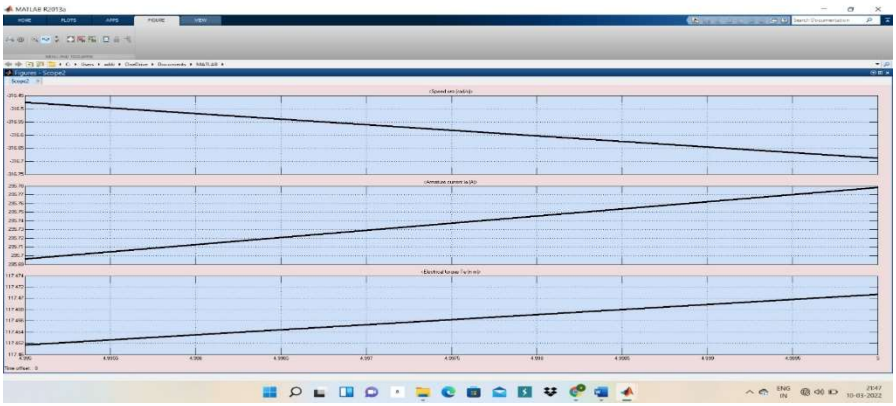
Graph(c)



Graph(d)



Graph(e)



Graph(f)

12. Conclusions

This paper consists of all the deep knowledge of the parts used in an electric vehicle with proper designing, modelling, simulation and analysis on software and all the correct calculated values for selection of hardwareparts. There were many challenges throughout the designing process. The selection of motor to achieve the required starting torque and top speed was a challenging task. Finally, a PMSM Motor of 72V and 5KW wasselected by conducting both theoretical and experimental studies and battery of rating 72V and 100ah capacity.

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