

Simulation of All Terrain Electric Vehicle Using MATLAB Simulink

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in Mechatronics Engineering
By

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**DEPARTMENT OF MECHATRONICS ENGINEERING
SCHOOL OF MECHANICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade “A” by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of A. Ezhumalai (38090006), S. Naresh (38090014) who carried out the project entitled "SIMULATION OF ALL-TERRAIN ELECTRIC VEHICLE USING MATLAB SIMULINK" under my supervision from 01.11.2021 to 10.05.2022.

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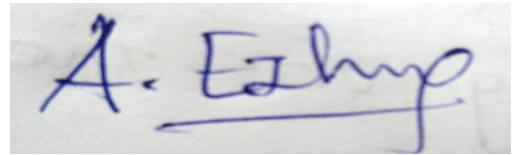
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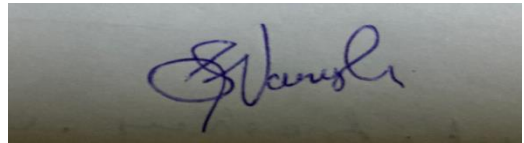
DECLARATION

I A. EZHUMALAI (Reg.No.38090006) and S. NARESH (Reg.No.38090014) hereby declare that the Project Report entitled "SIMULATION OF ALL TERRAIN ELECTRIC VEHICLE USING MATLAB SIMULINK" done by us under the guidance of Dr. J. LILLY MERCY is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechatronics.

1)

A handwritten signature in blue ink that reads "A. Ezhumalai". The signature is written in a cursive style with a horizontal line underneath the name.

2)

A handwritten signature in blue ink that reads "S. Naresh". The signature is written in a cursive style.

DATE: 10.05.2022

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SIGNATURE OF THE CANDIDATE

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TABLES OF CONTENTS

CHAPTER No	TITLE	PAGE No
	ABSTRACT	ii
	LIST OF FIGURES	iii
	LIST OF TABLES	v
1	INTRODUCTION	1
2	LITERATURE SURVEY	4
	2.1 LITERATURE SURVEY	4
3	AIM AND SCOPE OF THE PROJECT	10
	OBJECTIVE	10
4	MATERIALS AND METHODS	11
	4.1 SIMULATED VEHICLE MODEL	11
	4.1.1 Duty cycle	12
	4.1.2 Battery	13
	4.1.3 Motor and inverter	14
	4.1.3.1 Buck inverter	14
	4.1.3.2 Three-phase inverter	17
	4.1.3.3 Communication Logic	25
	4.1.3.4 Hall sensor	27
	4.1.4 Transmission	28
	4.1.5 Vehicle body	30
5	RESULTS AND DISCUSSIONS	35
	REFERENCES	43
	OUTCOME OF THE PROJECT	45
	JOURNAL PAPER FIRST PAGE	46
	PLAGIARISM CHECKER RESULT	47

ABSTRACT

Off-road Vehicles are one of the most common vehicles; they've been around since the mid-1970s, but their popularity has grown since then. On- and off-road mobility, as well as homesteading, valley rides, and slope climbing, are all possible with an all-terrain electric vehicle. New steering knuckles, a bunch board, ability turnover assurance, driver ergonomics, and private components are all part of the distinct and unique concept. An all-terrain vehicle (ATV), also known as a quad bicycle or simply a quad, is a low-pressure tyre-riding light utility vehicle (LUV) with a seat for the administrator and handlebars for controlling the vehicle. It is now being studied to deal with a broader range of landscapes than previously thought. It has been designed to handle a wider range of terrain than most other vehicles. The rider sits and controls these vehicles similarly to a cruiser, but the extra wheels provide more stability at slower speeds. Despite the fact that most have three or four wheels, six-wheel versions are available for specific applications. The information values for various parts, such as the motor, tyres, and stopping mechanism, are either taken from the MathWorks website or default values are used. Finally, different vehicle result boundaries will be considered in order to quantify vehicle behaviour. We present a MATLAB/Simulink model for electric all-terrain vehicles in this paper (ATVs). We model the EVs' vehicle components, transmission execution, and battery to determine the battery's power requirements and then determine the best types of velocity to use for various applications. The re-enactments are carried out with the help of MATLAB code and Simulink blocks. The vehicle's speed and distance travelled were compared to real-world driving cycles and force variations of an EV. This model's added value is that it accurately reproduces the streamlined drag, direct speed increase, and moving obstruction powers that were observed.

LIST OF FIGURES

FIGURE No	TITLE	PAGE No
4.1	Electric All-Terrain vehicle	12
4.2	Block parameters: Duty cycle	12
4.3	Battery circuit	13
4.4	Circuit of motor and inverter	14
4.5	Buck converter circuit	15
4.6	Average -Value DC-DC Converter	15
4.7	Voltage sensor	16
4.8	Three phase inverter	18
4.9	Line Voltage sensor (Three phase)	19
4.10	Current sensor (Three phase)	19
4.11	Converter (Three phase)	20
4.12	Block parameters: Converter (Three phase)	21
4.13	Six phase Gate Multiplexer	21
4.14	Block parameters: BLDC	23
4.15	Brush commutator	26
4.16	Hall Sensor	27
4.17	Motion sensor	28
4.18	Block Parameters: Motion sensor	28
4.19	Transmission	29
4.20	Simple gear	29
4.21	Block parameters: Simple gear	30
4.22	Vehicle structure block	31
4.23	Block parameters: Vehicle body	31
4.24	Tire (Magic formula)	32
4.25	Double shoe brake	33
4.26	Block parameters: Double Shoe brake	33
5.1	Taguchi Optimization graph (velocity optimization table)	38
5.2	Taguchi Optimization graph (three-phase voltage)	39

5.3	Taguchi Optimization graph (three phase current)	40
5.4	Vehicle velocity	41
5.5	Three phase current	41
5.6	Three phase voltage	42

LIST OF TABLES

TABLE	TITLE	PAGE
No		No
4.1	Current and voltage equations	16
4.2	Rotor Specifications	24
4.3	Stator specifications	24
4.4	Magic formula coefficient for typical road inclination	32
5.1	Factors and Levels	36
5.2	Taguchi L27 Orthogonal array- Simulation and results	36
5.3	Taguchi Response table	37

CHAPTER 1

INTRODUCTION

An electric vehicle (EV) is accelerated by an electric motor rather than an internal combustion engine (IC engine). The battery is used to power the electric motor. Electric vehicles provide the opportunity to connect the renewable energy and low-carbon transportation sectors. Because of the country's high fuel prices, the use of electric vehicles has increased dramatically. Automobiles are primarily used for on-road transportation. The all-terrain vehicle is a newer segment of a small vehicle that is popular in North America. Honda Motor Company introduced the first commercial all-terrain vehicle, the ATC90, in 1970. This vehicle was a simple three-wheeled vehicle powered by a small 90cc ICE. Initially, the vehicle was intended to be used for recreational purposes. Three-wheeled vehicles kept getting better, which eventually led to the four-wheeled vehicles we use today. They are still used for fun, but high-performance and agile vehicles are used in a lot of different ways, like for farming, forestry, natural resource exploration, law enforcement, and peacekeeping. However, this preliminary investigation is done to figure out how much power and torque the car needs at first. This thesis talks about and looks at how to go from a gas-powered all-terrain vehicle (ATV) to an electric one. Preliminary tests are done to figure out how much power and torque the car needs at the start. Mechanical load simulation models are made and compared to data from the manufacturer. It doesn't always work, even though it's done. The electromagnetic transient simulation program is used to combine the load model with a simulation of the electric drive and motor (PSCAD). Using the simulation results, a vehicle prototype is built by choosing the most important parts. These include an electric traction motor, batteries, and a custom motor drive. Both the results of the simulation and the prototype are compared and looked at. This is especially true in all-terrain driving, where TV control can help the vehicle stay stable while also improving efficiency. The study reviews the current state of TV control and introduces a novel methodical approach for creating TV control systems for all-terrain electric ground vehicles in this setting. This method employs separately controlled electric power trains to modify the vehicle's dynamic characteristics in

both steady-state and transient situations. The purpose of the design of this electric vehicle is to develop an off-road vehicle that can be utilized for transit in hilly locations, farms, and as a dependable weekend experience for enthusiasts. Various factors of an electric vehicle's design must be examined to fulfil this task. This is what I focused on when I looked at the parts of the car. The chassis, drivetrain and suspension were the parts that I looked at. Because these vehicle components were thought to have the greatest impact on the off-road driving experience, they received the most time and attention in their design and execution. Consumer interest was always the primary goal throughout the design process, which employed innovative, low-cost, and successful methods. This study employs a system identification technique to describe and analyse the path-following planning motion of an All-Terrain Vehicle (ATV) in terms of yaw stability. The mathematical modelling is done in the form of a state space equation, and the parameters are determined by measuring the prototype ATV in the field. The open loop system is simulated with this model option, as well as the output is checked through using system identification to make sure it works. The investigation results for prototype ATV yaw stability are validated using a system identification method with a step response methodology. Due to the increased pollution caused by gasoline engines, the automobile industry began producing electric vehicles. As a result, there will be no transportation issues in the future. This paper will discuss off-road terrain electric vehicles that can travel the greatest distance possible. Off-road terrain electric vehicles will make transportation easier in forests, hilly areas, deserts, and mining areas. All-terrain vehicles (ATVs) are vehicles used in motorsport, tourism, agriculture, and defence. It is more popular in Europe, North America, and South America. Despite its enormous potential, the Indian ATV market is still underdeveloped. The purpose of this paper is to investigate existing and future potential consumers' perceptions of an all-terrain vehicle in India, as well as to identify the reasons for the low number of units sold and to provide an opinion on the ATV's overall performance. It also briefly examines the requirements for an ATV to enter the agricultural sector in India, as well as a method for transitioning the market from underdeveloped to emerging market potential. The roll cage, chassis architecture, steering structure, deceleration mechanism, and power train configuration of an All-Terrain Electric Vehicle are all examined in this inquiry report. The vehicle is designed to explore rough environments that are inaccessible to

traditional vehicles. It is also designed to be economically feasible. By implementing the framework, the design attempts to improve on the current concept. Different structural approaches, which are specifically indicated in the automobile safety requirements, were given top attention when designing the vehicle. The study went over detailed step-by-step calculations of forces on each component, as well as simulations with an appropriate level of precision. Following the methodology demonstrated in the study will be beneficial in the development of a Light ATV; additionally, the suggested simulations will ensure the vehicle's safety. The vehicle industry has taken a turn with the introduction of Electric Vehicles as a result of technological advancements. Electric vehicles benefit humanity by providing a sustainable mode of transportation that is not harmful to the environment. This paper describes how to model an electric vehicle in MATLAB and Simulink, including how to create a motor model, a battery model, a power model, and a regenerative system. The objectives of this study include simulation of the vehicle model during constant duty cycles, inclination, wind velocity, start without any external actuation on flat terrain, etc., Simulating the model by adding variable terrain and inclusion of generic combustion engine block in the model is also done.

CHAPTER 2

LITERATURE SURVEY

2.1 LITERATURE SURVEY

[1] Abdullah, MohdAzmana, TamaldinNoreffendyb, RamliFaizRedzac, SudinMohdNizam, "Design and Development of Low Cost All-Terrain Vehicle (ATV)", Applied Mechanics and Materials- (2014) - This project focuses on the practical and engineering applications of the subject's vehicle dynamics and automobile technology, which are covered in the course. The power train is powered by a 110CC four-stroke motorbike engine with a clutch. Design and analysis are carried out using CAD software, which is always being developed and researched, and the ATVs are exposed to continuous improvement. The selection of materials, the application of design principles, and the availability of components all contribute to the long-term viability of ATV design and development.

[2] Babus A.K, "Automotive Chassis", 2008 Chapter 3 - Different loads that are occurring on the chassis can be read at various points. Because of this, they have chosen the material based on the strength that we want it to have.

[3] Cherefiles, A.R., Filizadeh, S., "Modeling and Transient Simulation of an All-Electric Terrain Vehicle (ATV), 2007 - The creation of an electric ATV was described in the thesis. The preliminary design was carried out in a transient simulation programme (PSCAD), which allowed for a comprehensive software model of both the mechanical and electrical systems. This simulation enabled the control system settings to be optimised. A prototype was then built using the simulation findings to compare and assess the outcomes. The following points provide further information on this work's contributions. PSCAD was used to perform an electromagnetic transient simulation. For the first component selection, standard library components were paired with a thorough custom created vehicle load model.

[4] Dennis Doerffel, Soleiman Abu Sharkh, "A Critical Review of Using the Peukert equation for Determining the Remaining Capacity of Lead-acid and Lithium-ion Batteries", April 2006 -In many applications, it's critical to be able to anticipate a

battery's remaining capacity with confidence, accuracy, and simplicity. In some cases, different versions of Peukert's empirical equation can be used to figure out how much capacity is left in a lead-acid battery that is being charged with a variable current. Peukert's empirical equation connects the available capacity to the charge current. This study looks at all of these strategies based on the results of experiments with two commercial lead-acid batteries. In light of tests done on a lithium-ion power battery, Peukert's equation-based methods are also looked at in terms of lithium-ion batteries.

[5] Deep Shrivastav, "Designing of All Terrain Vehicle (ATV)", December 2014 - The goal of developing a single-passenger off-road race car with high safety while keeping cheap production costs appears to have been met, as proved by this study. Preliminary testing will demonstrate that our design should increase the lifetime of all vehicle systems, and any major corrections should be made as a result.

[6] Denish S. Mevawala, Mahesh P. Sharma, Devendra A. Patel, Darshan A. Kapadia, "Stress Analysis of Roll Cage for an All-Terrain Vehicle", 2014 (ICAET2014) - The primary focus of this paper is the roll cage. A roll cage enhances a vehicle's appearance. To evaluate the roll cage's strength requirements, stress analysis is performed using the FEA program ANSYS workbench. The design of an ATV roll cage is discussed in this article, as well as alternative loading tests such as front-impact, side-impact, and rear-impact. ANSYS software is used for modelling and stress analysis. To enhance vehicle performance while reducing roll cage failure, we worked on every aspect of the gear box.

[7] Dur Mathias, Cruden Andrew, Sinclair Gair; J.R. McDonald, "Dynamic Model of a Lead-acid Battery for Use in a Domestic Fuel Cell System", Oct. 2006 - The car industry is driven to explore for alternative energy sources due to the limited availability of fossil fuels and the high rate of usage of this energy for transportation. One of the solutions may be electric and hybrid automobiles. Enhanced electric motors, power electronics, an integrated automatic transmission controller, and energy storage technologies like as batteries and ultra-capacitors may increase the vehicle's efficiency. Because integrating the bulk of these components in a drive

train configuration can be difficult, computer simulation and modeling before manufacturing can save time and money while improving design performance.

[8] Filizadeh S, A.R.Cheverfils, D.R.Northcott “Analysis and Design of Vehicular Power Systems Using PSCAD/EMTDC”, 2007 - The construction of a thorough mechanical model linked with a model of a synchronous permanent magnet ac (PMAC) motor and torque vector control system is investigated using an electromagnetic transient simulation tool, PSCAD/EMTDC. The mechanical model's features will be presented briefly, followed by a discussion of both the electrical motor.

[9] Gao, D.W.Mi, C.Emadi, A., “Modeling and Simulation of Electric Hybrid Vehicles”, April 2007 - The findings of modelling and analysis of various vehicles for power generation have supplied adequate proof supporting the aforementioned potential. The same was modelled and found to be functional, however it is not viable to create without the vehicle's extra infrastructure. The simulation is done using the MATLAB/Simulink and the Vehicular Simulation Tool. For the driving cycles used for the various load levels, there is no discernible difference in fuel usage. Vehicular distributed generation, where the transport operators' region is a scattered area of generation, is extremely likely in the near future. They play an important part in the energy business.

[10] Grzegorz Szczesniak, Paulina Nogowczyk, RafalBurdzik, “Some basic tips in vehicle chassis and frame design”, Journal of measurement in engineering-December 2014 - In this article, the several critical stages of vehicle manufacture are covered, which is the design of the chassis and frame. Also, some examples of SSS for design concepts in car manufacture have been illustrated. Some short information regarding chassis and frame types utilised in special vehicles has been a lot helpful. These challenges are particularly significant for vehicle designers, especially during assumptions and constructions of chassis and frames.

[11] Hirak Patel, Khushbu C. Panchal, Chetan S. Jadav, “Structural Analysis of Truck Chassis Frame and Design Optimization for Weight Reduction” - FEA can be used to easily analyse the chassis structural system, which is the focus of this

report's work: optimising the automobile chassis under constraints of maximum shear stress and deflection. An analysis of weight loss is carried out. So, a finite model of the chassis is needed. Pro-E is used to model the chassis, and ANSYS is used for FEA.

[12] Masanori Yoshihara, "The Influence of Body Layout on Vehicle Pitching Behaviour in ATV", 2001 - To clarify the impacts of body shape on ATV pitching behaviour and aid in the development of a more pleasurable product, this study offers to verify the following: it presents the study results based on theory and experiment concerning the effect of body geometry on vehicle dynamics, with a special emphasis on vehicle characteristics under acceleration and deceleration. Several aspects that contribute to pitching motion are addressed in the context of vehicles that use a chain drive or swing arm system.

[13] Naresh Rajput, Er. Gaurav Mehta, "Modelling & Finite Element Analysis (FEA) Of ATV Chassis To Enhance Efficiency", International Journal of Advances in Engineering & Scientific Research-AprJun-2016 - This paper describes their efforts to create and design an ATV chassis and to conduct a finite element analysis of the chassis using several software packages required by the SAE in order to develop a durable and efficient ATV chassis design for off-road vehicles. Using simulations, it is proved that the requisite adequate dynamic stability may be achieved when maneuvering across rugged terrain.

[14] Nasar S A and LE "Unnewehr, Electromechanics and Electric Machines", Second Ed., United States of America, John Wiley & Sons. Inc., 1993 - The fundamentals of simulation and numerous modelling approaches were explained in relation to the vital importance of simulation and modelling in the design process of hybrid cars. Several aspects of the sequence drive train, including vehicle dynamics, battery, engine, electric machine, automatic driver, tyre, and energy coordination and monitoring system, were modelled to construct a series hybrid bus.

[15] Onoda, S.; Emadi, A., "PSIM-based Modeling of Automotive Power Systems: Conventional, Electric, and Hybrid Electric Vehicles", March 2004 - By developing module boxes for not just the electrical systems, but also the mechanical, energy-storage, and thermal systems of the cars, this research explores the PSIM validity

as an automobile modelling tool. Internal combustion engines, fuel converters, gearboxes, torque couplers, and batteries are among these modules. Once these modules are created and saved in the library, the user may easily transform the automobile model into a conventional, electric, or hybrid vehicle by dragging and dropping them into a schematic blank page.

[16] Salameh, Z.M. Casacca, M.A. Lynch, W.A, "A Mathematical Model for Leadacid Batteries", March 1992 - It is vital to calculate the battery's Ampere-hour capacity for load leveling over a lengthy period of time when employing a battery energy storage system as an active power peaking station. The discharge simulation model for the battery, which was constructed for this purpose, considers the battery's voltage dependency on capacity and current and is based on battery measurements taken at constant discharging currents. The results were compared to the measured voltage and current profiles after the aforementioned model was used to mimic a typical load equalization operation. Almost all battery energy storage system reductions are achieved through lowering peak load, as previously stated. For successful peak load shaving, the simulation findings underscore the need to accurately select the active power reference value.

[17] Senthil Kumar M , C.D. Naiju, S. J. Chethan Kumar, Joseph Kurian, "Vibration Analysis and Improvement of a Vehicle Chassis Structure", Applied Mechanics and Materials - In this research, the existing chassis design is analysed, and the NVH characteristics of the vehicle are examined. Hyper mesh software is used to mesh the CATIA V5 3D model of the chassis and build a finite element model of the structure.

[18] Shiva Krishna, Amebesh Shetye, PrabhudevMallapur, "Design and Analysis of Chassis for SAE BAJA Vehicle", IOSR Journal of Engineering (IOSR JEN), August 2019 - Designing and analysing is a tough element of the process because these tests must be carried out with many constraints. With all of the time and study limits available, it has been a difficult task. This report included a timeline for every key task completed on the chassis build-up. According to the aims that have been met, the main purpose is to build a very well chassis structure that will be optimized on factors such as cost and weight.

[19] Upendra S. Gupta, SumitChandak, Devashish Dixit, "Design & Manufacturing of All Terrain Vehicle (ATV)- Selection, Modification , Static & Dynamic Analysis of ATV Vehicle",Feb 2015 - An in-depth overview of the design considerations, static and dynamic analysis and mathematical data involved in the design of an ATV vehicle is presented in this paper Design simplicity, great performance, ease of maintenance, and safety are all top priorities, and all of this comes at a fair cost. In the process of creating the ATV, engineers use a variety of methods, including material selection, stress analysis, frame, and chassis design, and simulations to test for any flaws.

[20] Williamson S., Emadi A., Rajashekara, "Comprehensive Efficiency Modeling of Electric Traction Motor Drives for Hybrid Electric Vehicle Propulsion Applications", July 2007 - Power electronic converters and electric propulsion motors have been demonstrated to be incredibly important components for contemporary hybrid electric vehicle (HEV) propulsion applications in recent study. As a result, during the driving schedule, it is critical that both the traction motor and the related drive work at peak efficiency. The traction motor and drive are employed across the whole torque/speed operational range in typical HEV propulsion applications. This work seeks to estimate inverter and motor losses/efficiencies over typical city and highway driving schedules in light of this reality.

CHAPTER 3

AIM AND SCOPE OF THE PROJECT

OBJECTIVE

- To Simulate vehicle model on constant duty cycles.
- To Simulate vehicle model on constant duty cycles and inclination.
- To Simulate vehicle model on constant wind velocity and inclination.
- To Simulate vehicle from the start without any external actuation on flat terrain.
- To Simulate vehicle model on 1 degree (or $\pi / 180$ rad) downward slope without a headwind.
- To Simulate vehicle model on 1 degree (or $\pi / 180$ rad) downward slope with 2m/s headwind.
- To Simulate the model by adding variable terrain.

CHAPTER 4

MATERIALS AND METHODS

4.1 SIMULATED VEHICLE MODEL

This is the main circuit diagram in which the whole model is depicted. In this, the duty cycle is connected to the motor and inverter block, due to which the motor will be actuated using the PWM Pulses. The supply is given through the Battery. From there the car transmission is connected to the terrain vehicle. Through this whole setup, the vehicle runs and shows the velocity in the graph.

The list of components used in this model is listed below:

- Duty Cycle
- Battery
- Motor and Inverter
 - Buck Converter
 - Three Phase Inverter
 - Commutation Logic
 - Sensor
 - BLDC Motor
- Transmission
- Vehicle Body

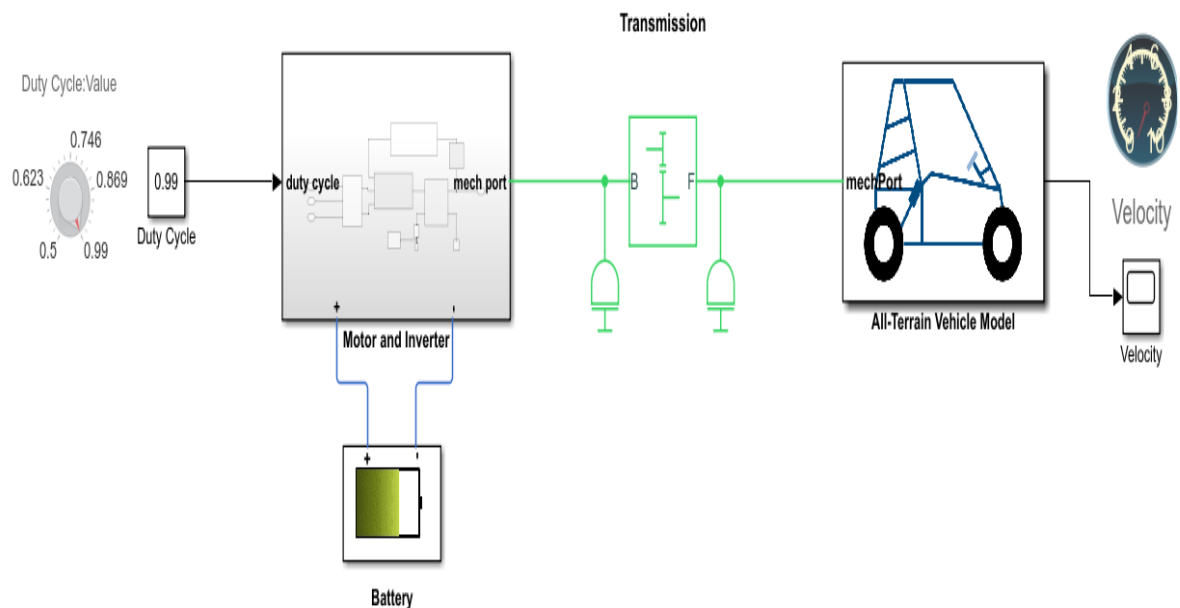


Fig: 4.1 : Electric All-Terrain Vehicle

4.1.1 Duty cycle

An input voltage and output voltage have a simple relationship defined by the duty cycle ratio, which is the ratio of TON to the total cycle length, which includes TON plus TOFF. With a higher duty cycle, more current can flow through the inductor and be sent to the output. During the off season, on the other hand, this transferring takes place.

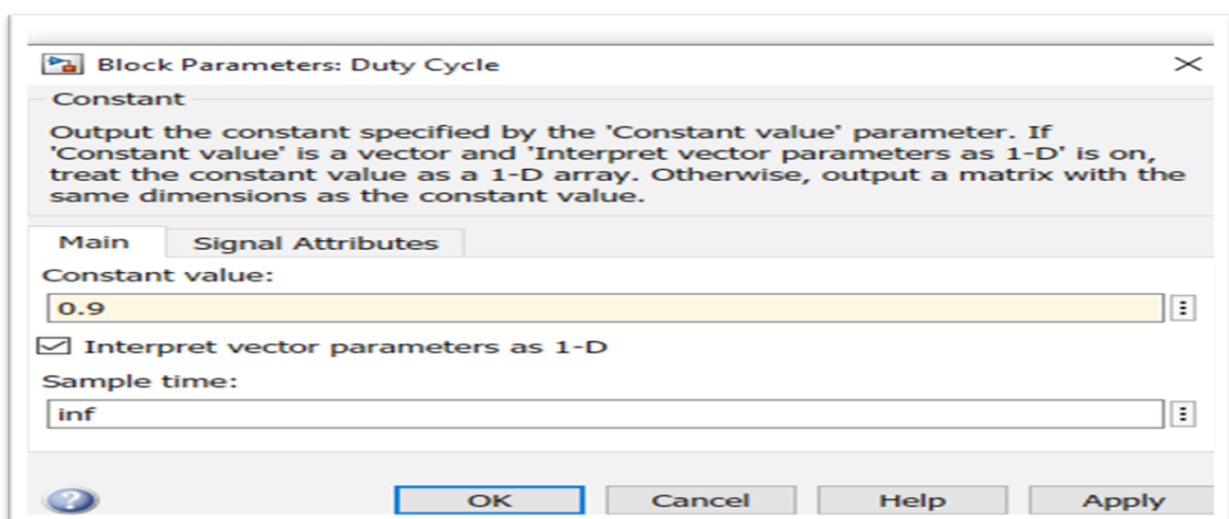


Fig: 4.2 : Block Parameters: Duty cycle

4.1.2 Battery

A power source made up of one or more electrochemical cells connected externally to power electrical devices is known as an electric battery. The cathode and anode of a battery are both referred to as the positive and negative terminals, respectively. There are electrons flowing through an external electric circuit from a negative to a positive terminal. Positive and negative ions in which high-energy reactants are transformed into lower-energy products are provided to the external circuit as electrical energy when a battery is linked with a load. The term "battery" primarily refers to a device with multiple cells, but it has now come to refer to single-cell devices. The battery's dc power is out into the buck converter's input. The buck converter lowers the input voltage (DC Power) and sends it to a three-phase inverter's input. The cells of a battery can be linked in series, parallel, or a mix of the two. When cells are linked, the voltage of the battery grows, but the capacity in ampere-hours (Ah) remains constant. As cells are connected in parallel or the voltage constant, the battery's capacity in ampere-hours (Ah) grows. The following figure shows the battery circuit.

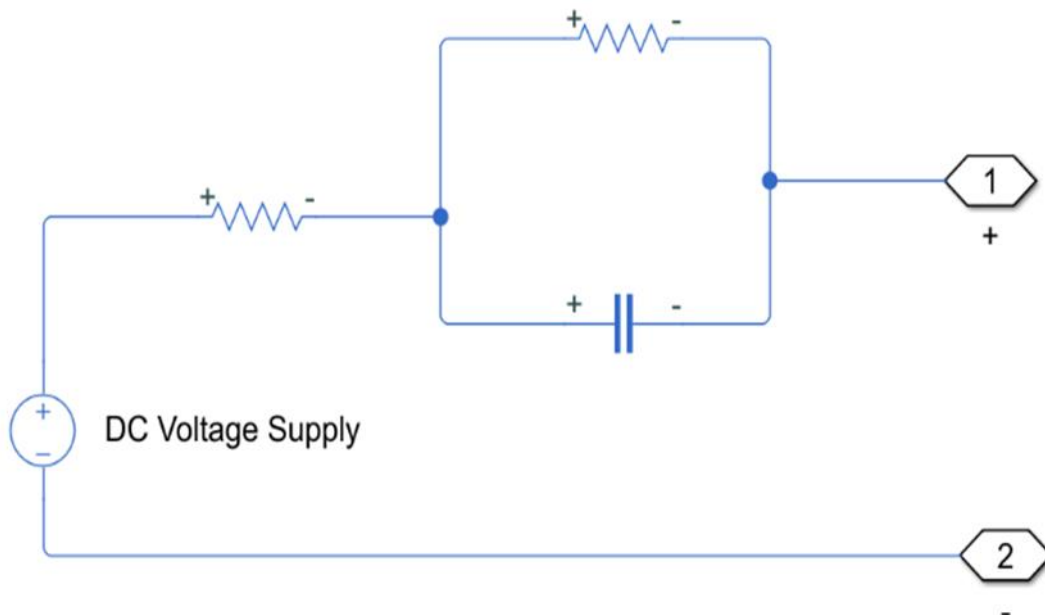


Fig: 4.3 : Battery

4.1.3 Motor and inverter

This is the Motor and the inverter module. In this, we have connected the Buck converter, which will reduce the high-power supply. Then the supply is transmitted to the three-phase inverter, for which the PWM pulses will be generated using the Commutation logic. Then a sensor is connected to the BLDC Motor, through which the motor will be act

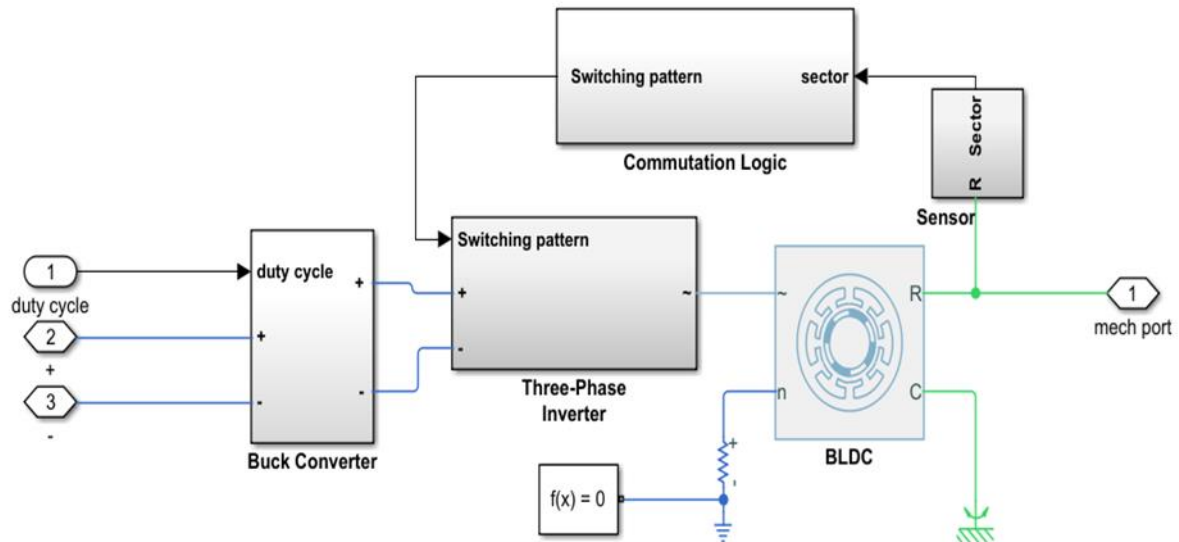


Fig: 4.4 : Circuit of motor and inverter

4.1.3.1 Buck converter

A basic DC to DC switching regulator is commonly known as a buck converter or step-down converter. Buck integrated circuits are available for purchase from controller makers. A step-down DC to DC converter is a device that can convert an input voltage to a lower output voltage (step-down, $V_{\text{output}} < V_{\text{input}}$). The buck converter is made up of a wave square-driven switch (made of a MOSFET), a diode, and an LC filter. The frequency of the PWM and the values of L_1 and C_1 determine the circuit's output voltage. The load might also affect the output voltage. The voltage on the inductance during the first phase while M_1 is in the ON phase and the diode is closed is $V_{\text{input}} - V_{\text{output}} = V_{L1}(\text{on})$. It is possible to disable power MOSFETs and IGBTs by reducing or boosting the voltage between the gate and source terminals of a Power MOSFET or the gate and collector terminals of an IGBT to zero. We can use a Buck converter to step down the voltage of the required input

to create the desired output. The ideal voltage sensor in the block converts voltage between any two electrical connections into a physical signal proportional to the voltage. The + and - connectors link the sensor to the circuit through electrical ports. A voltage-generating physical signal port. Connection V is a voltage-producing physical signal port. To get the needed output, we employed the Buck converter to step down the voltage of the given input.

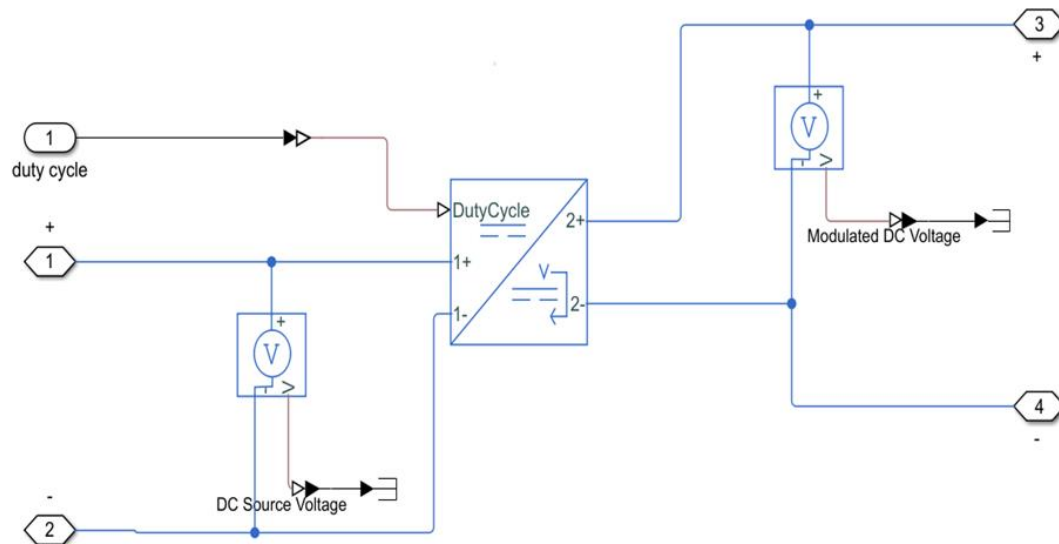


Fig: 4.5 : Buck converter circuit.

Average-Value DC-DC Converter

A regulated average value dc to dc converter is represented by the dc to dc Converter block. You may make the block a buck converter, boost converter, or buck-boost converter by altering the duty cycle. A similar circuit is shown in the schematic for the block that receives the duty cycle as input. The converter features a voltage and current source that may be regulated. To convert electrical energy between the linked components on either side of the converter, use the duty cycle, current reference, or voltage reference ports as control inputs.



Fig: 4.6 : Average -Value DC-DC converter

Current and Voltage Equations

Table 4.1: Current and voltage equations

Converter Type	Output Voltage	Input Current
Step Down Chopper	$V_2 = D \cdot V_1$	$I_1 = D \cdot I_2$
Step Up Chopper	$V_2 = V_1 / (1 - D)$	$I_1 = I_2 / (1 - D)$
Step Down - Step Up Chopper	$V_2 = D \cdot V_1 / (1 - D)$	$I_1 = D \cdot I_2 / (1 - D)$

Where,

- D - Duty Cycle
- V_2 - Output Voltage
- I_1 – Input Current

The I_1 current and power voltage are functions of the duty cycle and are dependent on the kind of converter once the Input signal parameter is set to the duty cycle. When the control input parameter for current reference is set, the converter calculates the voltage and calculates the output current. When the control input parameter is set to a voltage reference, the converter calculates the current and adjusts V_2 .

Voltage Sensor

The Voltage Sensor block is a model of an ideal voltage sensor or a device that converts voltage measured between two points in an electrical circuit into a physical signal. Connect the sensor in parallel with the block (or blocks) where you want to detect the voltage using the + and - ports. The measurement result is the output as a physical signal through port V. Connect this port to Simulink blocks like Scope or Display using the PS-Simulink Converter block.



Fig: 4.7 : Voltage sensor

4.1.3.2 Three-phase converter

The term "inverter" refers to a sort of power conversion (or power conditioning) circuit that operates from a direct current or alternating current source and converts it to alternating voltage or current in the field of power electronics. An alternating current to a direct current converter converts alternating current to a direct current, whereas the 'inverter' operates in the reverse direction. It is not uncommon for a utility alternating current supply to generate direct current for use in an inverter circuit even though the input is a DC source. It is possible to use an ac-to-dc converter and an inverter to "convert" utility alternating current to alternating direct current, but the final output may be different from the utility's original input alternating current in terms of frequency and voltage. Solar photovoltaic cells can create direct current voltage. A dc voltage source is one that has been converted from alternating current to direct current. The term "stiff" refers to a voltage source whose magnitude does not change when a load is applied to it. Voltage source inverters are all predicated on a constant input voltage. Uninterruptible power supply (UPS), adjustable speed drives (ASD) for AC motors, electronic frequency changers, and many other applications are all possible using voltage source inverters. Inverter devices, which are commercially available and utilised in homes and businesses to power some vital ac loads in the event of an interruption in the utility's ac service, are also familiar to most of us. The input dc voltage source for these inverter units is a battery supply, and the dc voltage is converted to a suitable frequency alternating current by an inverter circuit. The voltage on the dc bus limits the highest alternating current voltage that can be generated. For example, in a typical household inverter, the battery voltage may be as low as 12 volts, and the inverter circuit may only be capable of delivering an alternating current voltage of about 10 volts (peak). As a result, a transformer is utilised to boost the inverter output voltage to 230 volts, the voltage required by the load in this case. An inverter is a device that transforms direct current (DC) to alternating current (AC). We've already discussed the several sorts of inverters. A three-phase inverter converts a single-phase direct current supply to a three-phase alternating current supply. These are commonly employed in high power and variable frequency driving applications, such as HVDC power transmission. In a three-phase inverter, power can be sent across a network using three separate currents that are out of phase with each other, whereas in a single-phase inverter, power can only be transmitted through a single

phase. The inverter, for example, can be linked to one of the phases of a three-phase connection in your home. Because one of the three wires in a three-phase system carries a positive (or negative) voltage all across the cycle, shifting the panel output to different wires during each cycle can considerably minimise the requirement for storage. The converter hardware's price and complexity are reduced as a result of the reduction in energy storage, and its estimated lifetime is possibly increased. The block is a three-phase voltage sensor in its simplest form. It outputs a three-element PS vector after measuring the voltage between the phases of a three-phase electrical node. The device is a three-phase current sensor that is completely functional. It generates a three-element PS vector by measuring the flow of current across two three-phase electrical nodes. A three-phase inverter is used to convert a DC input to a three-phase AC output. To create a three-phase AC supply, its three arms are generally delayed by an angle of 120° .

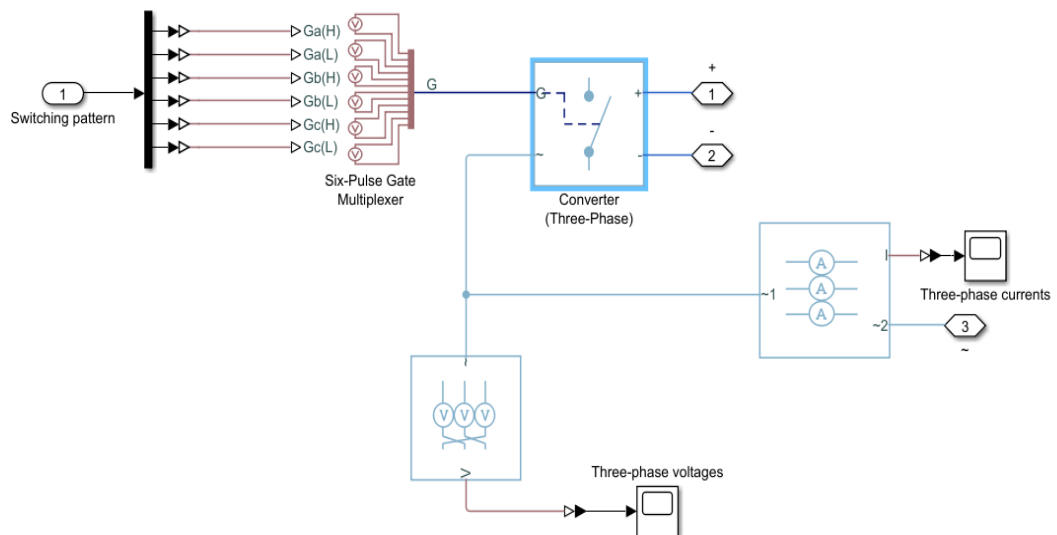


Fig: 4.8 : Circuit of 3 phase inverter

Line Voltage Sensor (Three-Phase)

The Line Voltage Sensor (Three-Phase) block is a three-phase line voltage sensor that is ideal. The block measures the three-phase system's line-to-line voltages and outputs a three-element physical signal vector. The voltage between the phases is proportional to each element of the physical signal output vector.

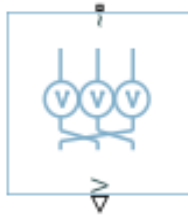


Fig: 4.9 : Line voltage sensor(Three phase)

Current Sensor (Three-Phase)

The Current Sensor (Three-Phase) block is a three-phase current sensor in its most basic configuration. The block measures and outputs a single three-element physical signal vector for each of the three currents flowing between ports 1 and 2. The physical signal output vector contains elements that are proportional to the current in each phase.

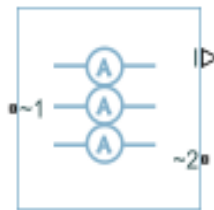


Fig: 4.10 : Current sensor(Three phase)

PULSE WIDTH MODULATION

An inverter's output voltage can also be modified by using a control within the inverter itself. Pulse-width modulation control within an inverter is the most efficient way to do this. The inverter is given a fixed dc input voltage, and the on and off durations of the inverter components are adjusted to provide a controlled ac output voltage. The most frequent method of adjusting the output voltage is by pulse-width modulation (PWM). PWM approaches have the advantage of being able to control the output voltage without the use of any additional components. Lower-order harmonics, as well as output voltage control, can be avoided or minimized using this strategy. Higher-order harmonics are easily filtered, hence filtering needs are lowered. The fundamental disadvantage of this technique is the expensive cost of SCRs, which must have quick on/off times. PWM inverters are widely used in industrial settings. PWM approaches are distinguished by pulses of constant

amplitude. The width of these pulses is regulated, however, to manage the inverter output voltage and lower the harmonic content.

Converter (Three-Phase)

Using the Converter (Three-Phase) block, a three-phase AC network can be converted to a DC one. An option for selecting a three-phase converter is available in the Converter (Three-Phase) block dialogue box.

- A thyristor is a gate-turn-off thyristor (GTO).
- Insulated-gate bipolar transistor (IGBT).
- As a field-effect transistor, a MOSFET is a type of metal oxide semiconductor.
- Thyristor.

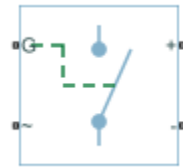


Fig: 4.11 Converter (Three-phase)

Antiparallel diodes are used in the averaged switch, which is a semiconductor switch. The [0,1] range is accepted by the G control signal port. An anti-parallel diode in place of the Ideal Semiconductor Switch block results in the averaged switch being either fully open or closed, depending on the value at port G. The averaged switch is partially opened when the value at port G is between 0 and 1. The PWM signal can then be averaged over a predetermined period of time. Using modulation waveforms instead of PWM signals allows for under-sampling of the model.

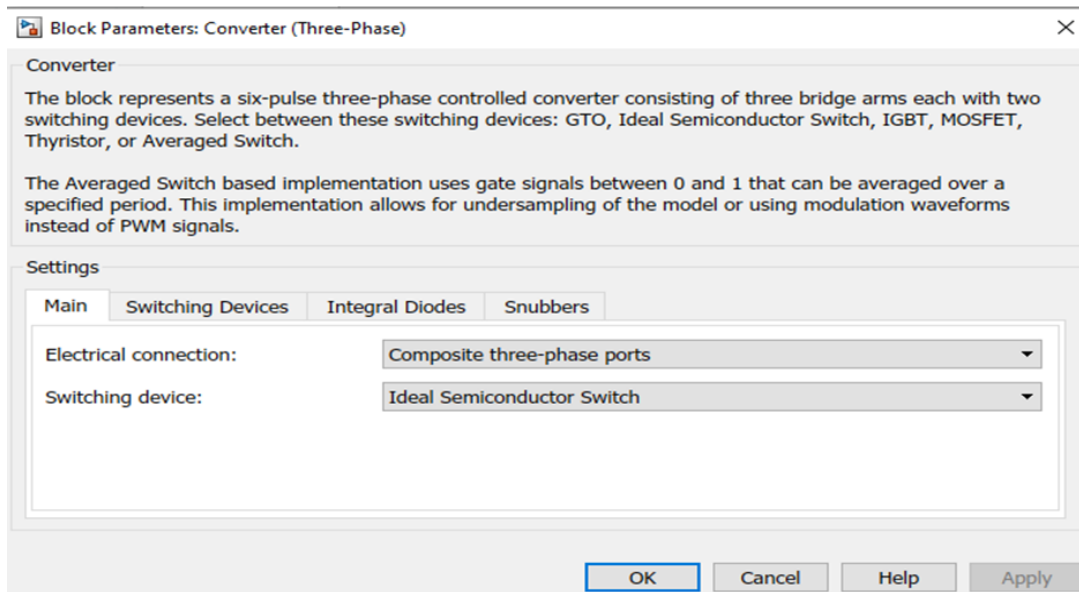


Fig: 4.12 Block parameters (Three-phase)

Six-Pulse Gate Multiplexer

There are six switching devices in a converter (three-phase) that receive gate voltage signals from a multiplexer block. Six gate signals are combined in the block. Electrical ports appear on the block when the inputs are switched to electrical ports. Phase voltages connected to high-side switching devices in the Converter (Three Phase) block and the common negative DC voltage that connects to each low-side switching device in the Converter (Three Phase) block are referenced by additional electrical ports.

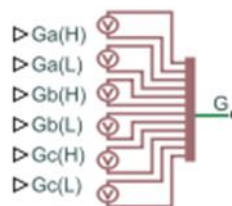


Fig: 4.13 : Six phase Gate multiplexer

BLDC Motor

When it comes to motor efficiency and torque-to-weight, electronically commutated or "brushless" motors are becoming more and more popular because of their superior electrical efficiency and weight-to-power ratios. Permanent magnet

synchronous machines (PMSMs) with trapezoidal back EMF are commonly referred to as brushless DC (BLDC) motors. Since PMSM motors have a sinusoidal back EMF due to the distributed stator windings, this distinguishes BLDC motors from PMSM motors. Electronically commutated DC motors without brushes are referred to as brushless DC motors (BLDC motors or BL motors). To regulate the synchronous motor's speed and torque, a controller feeds a steady stream of current into the windings of the drive motor. These motors can generate a lot of torque over a wide speed range because of their high efficiency. It is possible to overcome the problem of connecting the armature's current to the permanent magnets by using brushless motors. When it comes to electronic commuting, the options are nearly endless. They're well-known for their quiet operation and the fact that they can maintain torque even when they're not moving. The rotor and stator are the only two parts of a brushless DC motor. When it comes to electrical components, the rotor and stator are the two parts that rotate. Electromagnets are moved to the stator by means of permanent magnets attached to the rotor in a BLDC motor. Electromagnets are activated by high-power transistors that turn the shaft. In order to disperse energy, the controller makes use of a solid-state circuit.

Construction of Brushless DC motor

Permanent magnets are linked to the rotor of this motor, making it extremely efficient. The stator contains the current-carrying conductors, commonly known as armature windings. The process of converting electrical energy into mechanical energy is known as electrical commutation. The use of an electric switch circuit rather than a mechanical commutator is the primary design difference between brushed and bldc motors. Because the magnetic fields formed by the rotor and stator revolve at roughly the same frequency, a BLDC motor is classified as a synchronous motor. There are no current-carrying commutators to worry about in a brushless motor. The field inside a brushless motor is switched via an amplifier that is triggered by a commutating device, such as an optical encoder, and this is accomplished by a switching device.

Working Principle of BLDC Motor

A BLDC motor functions similarly to a brushed DC motor. When a current-carrying conductor is put in a magnetic field, it experiences a force, according to the Lorentz

force equation. The magnet will feel an equal and opposite force as a result of the reaction force. The BLDC motor's current-carrying wire remains motionless while the permanent magnet moves. The stator coils become electromagnets when they receive electricity from the source and begin to produce a constant field in the air gap. Switching produces a trapezoidal alternating current voltage waveform, despite the fact that the power source is direct current.

Rotor

When it comes to electric motors, generators, and alternators, the rotor is a moving component of the electromagnetic system that drives them. The interaction of the windings and magnetic fields causes torque to be generated around the rotor's axis, which causes the rotor to rotate.

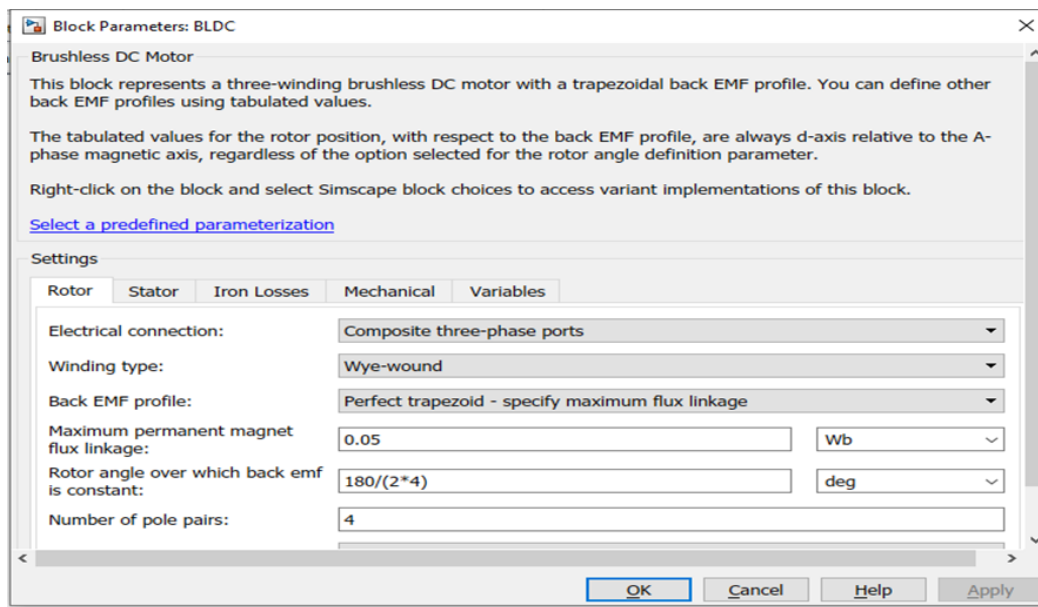


Fig 4.14 : Block parameters: BLDC

Rotor Specifications:**Table 4.2 : Rotor Specifications**

Electrical connection	Composites Three-phase Ports
Winding type	Wye-wound.
EMF profile from the back	Maximum flux linkage specified by a perfect trapezoid
Maximum permanent magnet flux linkage	0.05 Wb.
Rotor angle over which back EMF is constant	180/ (2*4) deg.
Number of pole pairs	4
Rotor angle definition	The angle between the phase magnetic axis and the q-axis.

Stator

The stator is the motor's stationary component, whereas the armature is the motor's rotating component. Direct current motors operate on the principle of a revolving magnetic field generated by the stator, which causes the armature to rotate.

Table 4.3: Stator specifications

Parameterization of the Stator	Specify Ld, Lq, and L0
Fidelity modelling	Constant Ld and Lq
Inductance of the d-axis of the stator, Ld	0.0001H
Inductance of the q-axis of the stator, Lq	0.0001H
L0 is the zero-sequence inductance of a stator.	0.00016H
Stator resistance per phase, Rs	0.001 ohm
Zero sequence	Include

Advantages of BLDC Motor

Because brushes aren't used, there's less overall maintenance. a smaller footprint with considerably greater thermal properties; and furthermore, the electric noise produced by the car is minimized. It has a variety of difficulties because it lacks a mechanical commutator. Because of its permanent magnet rotor, this motor has a high power to size ratio. Low friction enables speedier performance even when completely loaded and emptied. Brushed DC and induction AC motors are smaller and lighter. Because there are no brushes, the life expectancy is increased, the dynamic response is increased, electromagnetic interference is reduced, and noise is reduced. Furthermore, the commutator system does not require inspection or maintenance.

Limitations of BLDC motors

- These motors are pricey.
- The electrical controller that is necessary to regulate this motor is pricy.
- A large amount of driving circuitry is used.
- It is necessary to add more sensors.

Applications of Brushless DC motors

BLDC motors are used in a variety of applications, including industrial control, automotive, aviation, automation systems, and medical equipment. They are capable of dealing with fluctuating loads, constant loads, and positioning.

- Hard drives in computers and DVD/CD devices
- Automobiles that are electric or hybrid, as well as electric bicycles
- Belt-driven systems, industrial robots, and CNC machine tools are some examples of simple belt-driven systems.
- Compressors, washing machines, and dryers.
- Blowers, pumps, and fans

4.1.3.3 Communication logic

While getting into the specifics of BLDC motor feedback, it's important to understand why they're needed in the first place. BLDC motors are available in single-phase, two-phase, and three-phase configurations, with three phases being the most prevalent. Despite the fact that the number of phases is proportionate to the number

of stator windings, the number of rotor poles varies by application. Because the rotor is influenced by the stator poles of a BLDC motor, the stator pole position must be recorded in order to precisely drive the three motor phases. As a result, a motor controller is employed to establish a six-step commutation pattern in each of the three motor phases. During these six commutation periods, the permanent magnets in the rotor rotate the motor shaft, creating an electromagnetic field. The motor controller may then utilize a high-frequency pulse-width modulated (PWM) signal to efficiently lower the average voltage perceived by the motor, hence reducing motor speed, using this frequently influenced commutation sequence. This method also offers a lot of design freedom since it allows you to utilize a single voltage source for several motors, even if the DC voltage source is much higher than the rated voltage of the motor. This approach demands a very tight control loop between the motor and controller to preserve the efficiency advantages of brushed technology.

Brush commutator

In brushed engines, a commutator, which is a rotating switch located on the engine's shaft, is used to do this. It consists of a pivoting chamber insulated from the rotor's multiple metal contact points. The pieces are attached to the rotor's guiding windings. Brushes, formed of a sensitive transmitter like graphite, press on the commutator as the rotor rotates, producing sliding electrical contact with successive pieces. Brushes provide electric flow to the windings on a per-winding basis. The commutator selects various windings as the rotor rotates, and the directed current is dispatched from one of them, causing the rotor's attractive field to remain crisscrossed with the stator and produce force in a single b

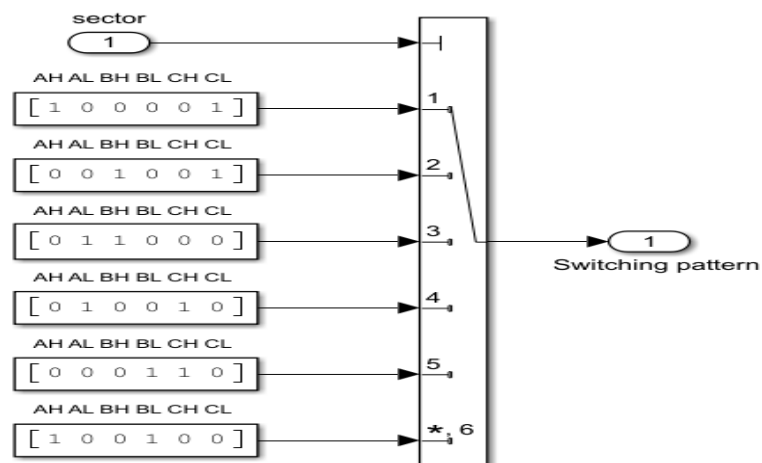


Fig: 4.15 : Brush commutator

4.1.3.4 Hall sensor

Magnetic sensors converted magnetic or magnetically encoded information into electrical signals for processing by electronic circuits, and we looked at inductive proximity sensors and the LDVT, as well as solenoid and relay output actuators, in the Sensors and Transducers courses. Magnetic sensors are solid-state devices that are getting more popular due to their versatility in applications such as sensing position, velocity, and directional movement. They're also a popular sensor choice for electronics designers because of its non-contact, wear-free functioning, minimal maintenance, and sturdy design, as well as the fact that sealed hall effect devices are vibration, dust, and resistant to water.

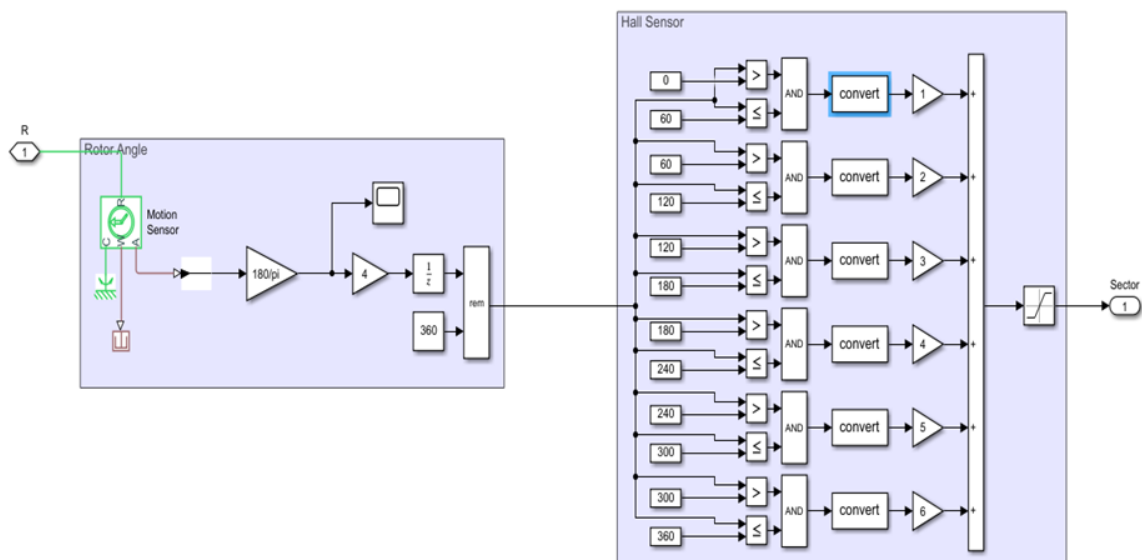


Fig: 4.16 Hall sensor

MOTION SENSOR

A motion detector is an electrical device that detects nearby motion using a sensor. A device of this type is frequently integrated as a component of a system that automatically performs a task or alerts a user of motion in a specific area. They are an important part of security, automated lighting control, home automation, energy efficiency, and other useful systems. The motion sensor block in a mechanical rotational network monitors angular velocity or angle. The sensor is ideal since it ignores inertia, friction, delays, energy consumption, and other variables. The physical signal ports W and A communicate the angular

velocity and angle of port R relative to port C, respectively. When the angular velocity at port R is greater than the angular velocity at port C, the measured angular velocity is positive

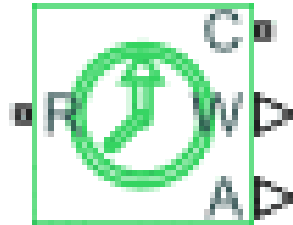


Fig: 4.17 : Motion sensor

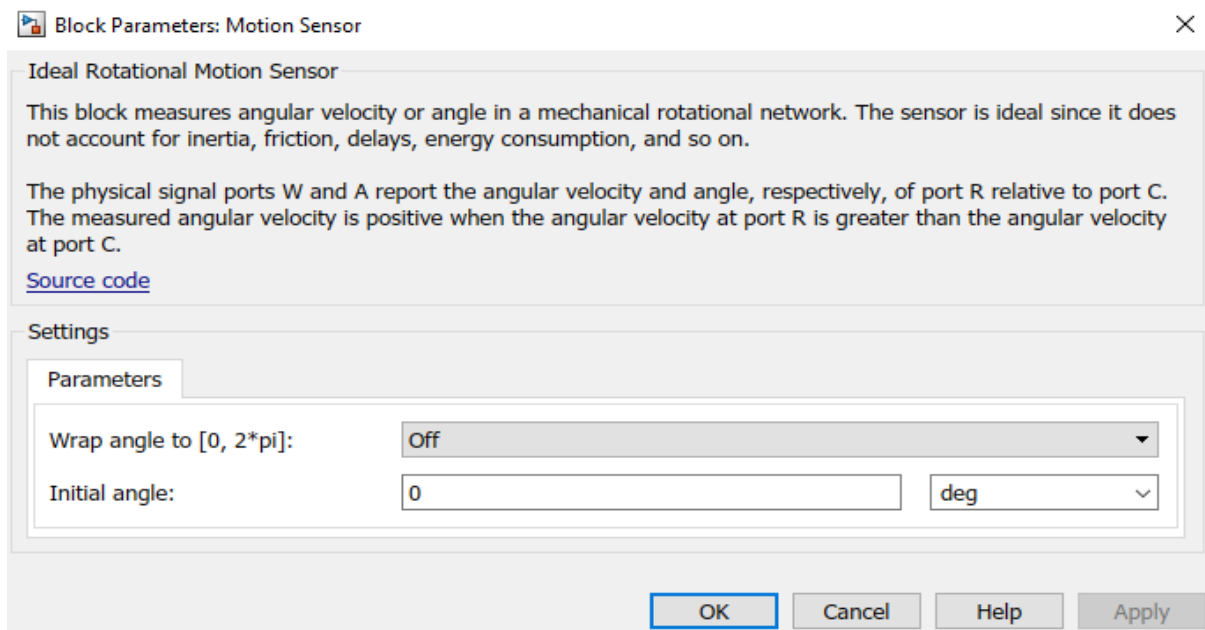


Fig: 4.18 : Block parameters: Motion sensor

4.1.4 Transmission

A vehicle transmission transmits the rotating power of the energy source, whether an electric motor or an internal combustion engine (ICE), through a set of gears to a differential, the unit that spins the wheels. The electric vehicle transmission systems are made up of a motor, an inverter, and a battery, all of which play an important role in the overall operation. A three-phase input to the stator produces a rotating magnetic field, which induces a current in the rotor and causes it to rotate.

The speed of the induction motor is defined by the frequency of the alternating current supply; the speed of the drive may be varied by changing the frequency of the power supply. A speed-varying gearbox is required for a combustion engine, but an electric vehicle may function at any speed and does not require one. A gearbox transmits the power from the electric vehicle's motor to the drive wheel. The EV features a single-speed transmission due to the efficiency of the motor.

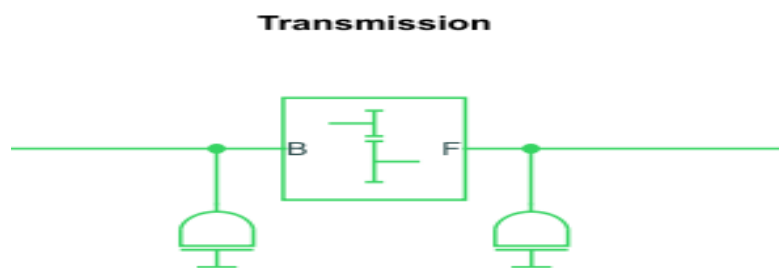


Fig: 4.19 : Transmission

Simple Gear

To ensure that the base gear B and the follower gear F rotate at the set fixed ratio, this block is called a "gearbox." You can choose whether the follower axis spins in the same direction as the base axis or in the opposite direction. A follower's (F) and a base's (B's) angular velocities are equal if they both rotate in the same direction. If F and B rotate in opposing directions, they have the same sign. These issues can be simply fixed or added to the system.

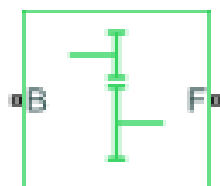


Fig: 4.20 Simple gear

By default, the block has just one mechanical translational conserving port. The block's positive direction is from the port to the reference point. When inertia is accelerated in a positive direction, the torque produced by inertia is positive.

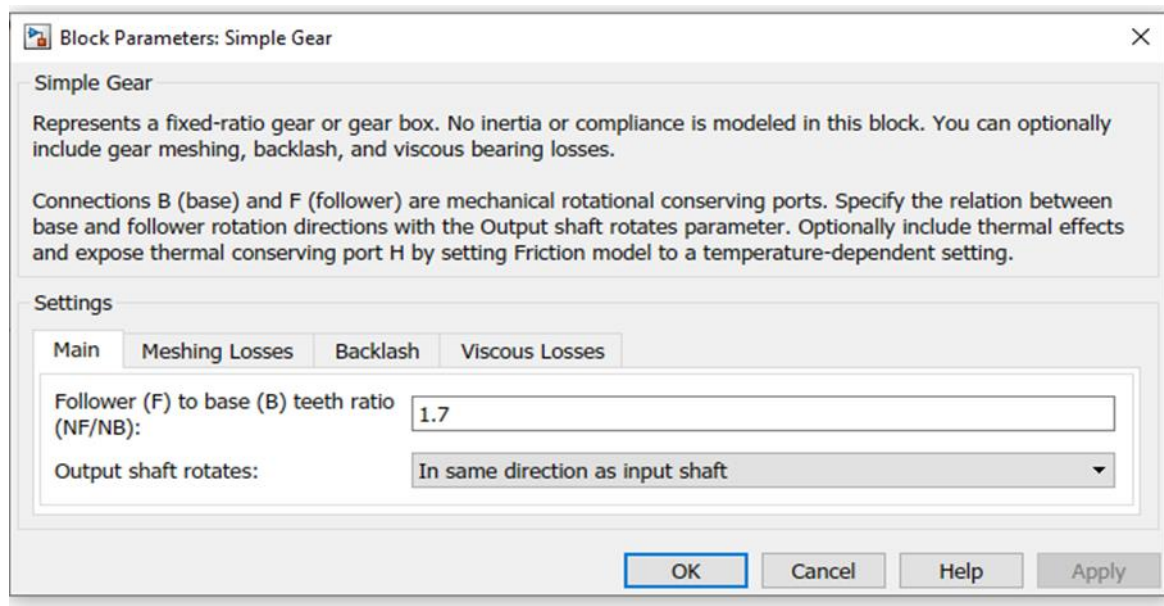


Fig: 4.21 : Block parameters: Simple gear

Vehicle dynamics

The cumulative effect of all the forces and torques acting on the vehicle causes it to move. The vehicle is propelled forward or backward by longitudinal tire forces. The vehicle's mass acts through its centre of gravity (CG). The weight drags the car to the ground, either backward or forward, depending on the inclination slope. Aerodynamic drag slows the vehicle down whether it is moving forward or backward. The drag is considered to act through the CG for simplicity's purposes.

4.1.5. Vehicle Body

The body of a two-axle vehicle in longitudinal motion is shown. Body mass, aerodynamic drag, road inclination, and weight distribution between axles owing to acceleration and road profile are all evaluated by the block. Each axle of the vehicle may have the same or different number of wheels. Pitch and suspension dynamics, as well as mass and inertia variations, are all conceivable. On the ground, the car is not traveling vertically. Connection H represents the motion of the vehicle's body. The traction motion produced by the tire should be attached to this port. The physical signal output ports for vehicle velocity and front and rear normal wheel forces are indicated by connections V, NF, and NR, respectively. Wheel forces that operate downhill are known as positive wheel forces. The speed of the headwind and the angle of the road are represented by the physical signal input ports W and beta,

respectively. When the changing mass is simulated, the physical signal input ports CG and M are revealed. The x and y distance offsets between the vehicle CG and the additional load mass CG are stored in CG, which is a two-element vector. The physical signal port J accepts the increased mass's inertia on its own when both changing mass and pitch dynamics are present.

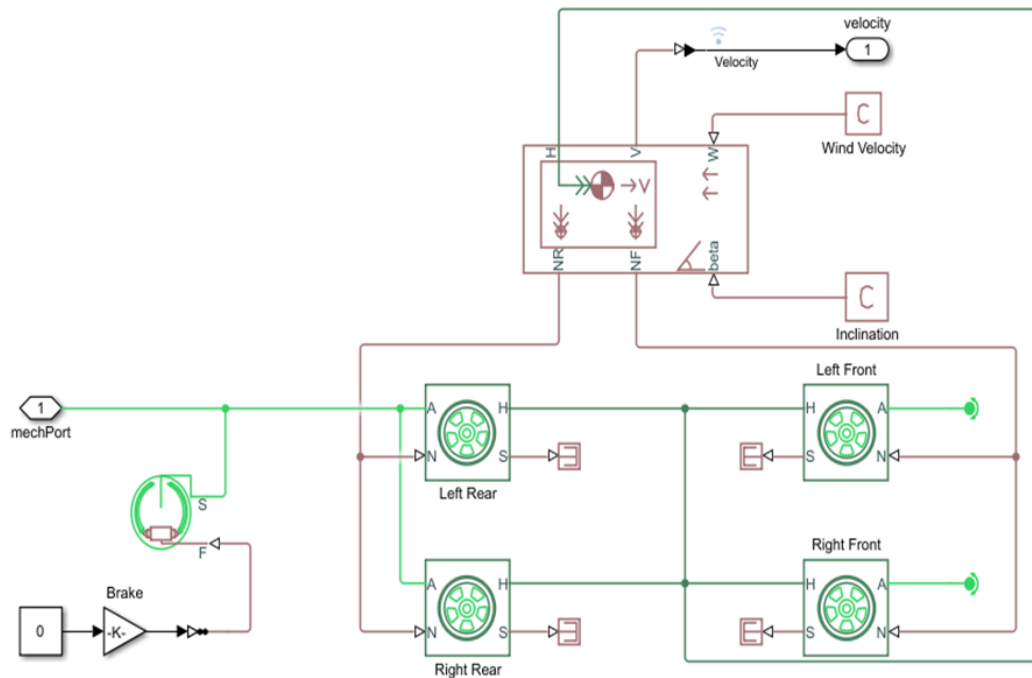


Fig: 4.22 : Vehicle body

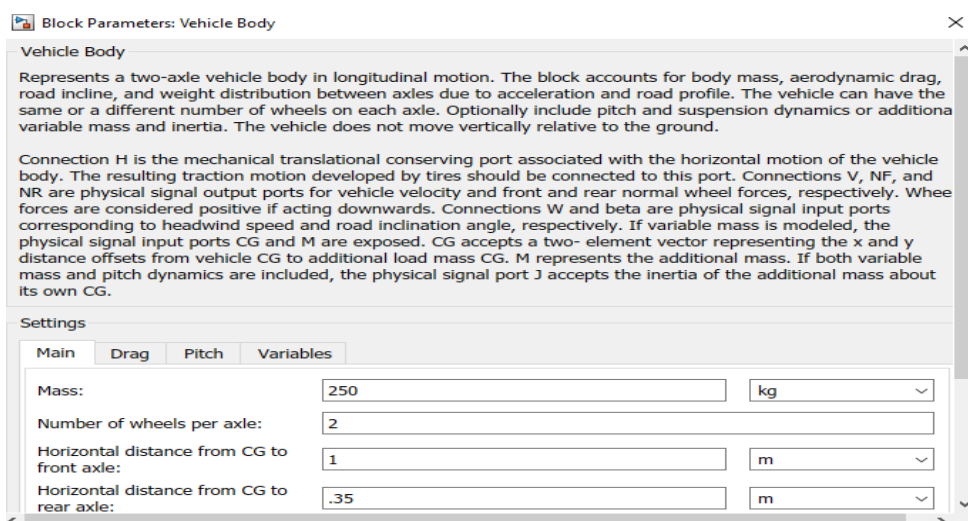


Fig: 4.23 : Block parameters: Vehicle body

Tire (Magic Formula)

The Magic Formula can be used to characterise the longitudinal behaviour of a highway tyre. The Simscape Foundation Library and the Tire-Road Interaction (Magic Formula) are also included. The building is built using wheel and axle blocks. Tire inertia, stiffness, and damping effects can be added as an optional feature. For the wheel axle, Connection A is the mechanical rotational conserving port. The mechanical translational conserving port of the wheel hub is where the tire's thrust is applied to the vehicle, and it is through this port that the tire's thrust is applied to the vehicle. The tire's normal force is applied to the wheel through Connection N, which is a physical signal input port. A positive force acts downward. Connection S, a physical signal output port, is where tyre slip is reported. By setting Parameterize by to Physical signal Magic Formula coefficients, you can define whether or not to disclose physical signal port M. Physical signal port M accepts a four-element vector containing the values of the Magic Formula coefficients B, C, D, and E, respectively.

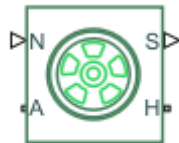


Fig: 4.24 : Tire (Magic Formula)

Magic formula coefficient for typical road inclination:

Table 4.4: Magic formula for typical road inclination

Surface	B	C	D	E
Dry	10	1.9	1	0.97
Wet	12	2.3	0.82	1
Snow	5	2	0.3	1
Ice	4	2	0.1	1

Double-Shoe Brake

A brake consists of two pivoted stiff shoes that are symmetrically placed inside or outside of a drum and are operated by a single actuator. As a result of the actuator force, the shoes apply friction torque to a shaft connected to the drum. Connection S is a rotational terminal for conserving energy that is connected to the drum shaft. Connection F is a physical signal port that represents the actuator's force input. Positive force generates friction torque, which prevents the shaft from rotating. Set Thermal port to Model to include thermal effects and expose thermal conserving port H.

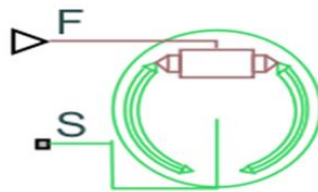


Fig: 4.25 : Double-Shoe brake

Block Parameters: Double-Shoe Brake

Double-Shoe Brake

Represents a brake arranged as two pivoted rigid shoes symmetrically installed inside or outside a drum and operated by one actuator. The actuator force causes the shoes to exert a friction torque on a shaft connected to the drum.

Connection S is a conserving rotational terminal associated with the drum shaft. Connection F is a physical signal port representing the force input to the actuator. Positive force creates friction torque that resists shaft rotation. Optionally include thermal effects and expose thermal conserving port H by setting Thermal port to Model.

[Source code](#)

Settings

Geometry	Friction	Faults
Drum radius:	150	mm
Actuator location radius:	100	mm
Pin location radius:	125	mm
Pin location angle:	15	deg
Shoe beginning angle:	5	deg
Shoe span angle:	120	deg

OK Cancel Help Apply

Fig: 4.26 : Block parameters: Double Shoe brake

The Double-Shoe Brake block, which is made up of two pivoted strong shoes that press on a circular drum to create braking action, is an example of a frictional brake. In opposed designs, the stiff shoes are positioned inside or outside of the rotating

drum. Because an actuating force is present, the stiff shoes press up against the turning drum. Due to friction between the revolving drum and the rigid shoe surfaces, the spinning drum slows down. In a range of applications, including motor vehicles and some heavy machinery, double-shoe brakes are utilized to generate significant braking torque with minimal actuator deflections. The model parameters may be simply created using commonly known brake form and friction values.

Tires and Brakes Modeling

Through their wheel axle rotational ports, the right and left tyre blocks absorb driveline torque and rotation from the transmission (A). At the wheel hub translational ports, the torque and rotation of a normal or vertical load (N) are converted to a thrust force and translation (H). The tires move before they can completely offer grip and respond to the road surface due to their uneven rotation. The left tire slip is captured as a physical signal, which is then translated to Simulink for use with the Tire slip scope. A brake with two pivoted stiff shoes positioned symmetrically within or outside of a drum and operated by a single actuator is seen in the Double-Shoe Brake block.

Vehicle Body and Load Modeling

By specifying the vehicle form, mass, aerodynamic drag, and beginning velocity, the Vehicle Body block completes the model's driveline connection line sequence (zero). The normal forces that the Tire blocks take as vertical loads are created by this block. Through its horizontal motion translation port, the vehicle body accepts the imparted thrust force and motion (H). A wind speed (W) and a road slope (beta), both physical constants, are also incorporated into the vehicle body model. The tire blocks receive the vertical load force from the back wheel (NR). Delivering a vertical weight to the front wheel is not required (NF). The subsystem output converts the vehicle's forward velocity (V) and reports it to the Vehicle velocity scope.

Reduced noise pollution

As electric cars are significantly quieter, they help to reduce noise pollution. Electric motors can provide a smoother driving with greater acceleration over longer distances. Many electric car owners have reported annual savings of up to tens of thousands of dollars.

CHAPTER 5

RESULTS AND DISCUSSIONS

The goal of the study is to optimise the velocity, current and voltage for a predetermined terrain environment. Using the simulated vehicle, keeping the Duty Cycle, Wind velocity and Road inclination as the varying factors the results were generated. The simulation was conducted using Taguchi L27 orthogonal array of Design of Experiments. The effect of these input factors on the output responses were optimised using Taguchi Response table.

Taguchi Optimisation Table

The Taguchi Approach is an eight-step process/product optimization method that entails planning, performing, and analysing matrix experiment data in order to determine the optimal control parameter quantities. Even when noise inputs are present, the main objective is to keep the output variance as low as possible. The Taguchi methodology is one of the most effective experimental procedures for identifying the fewest number of trials that must be performed within a given set of components and levels. Optimization in the Taguchi Method refers to identifying the best values for control parameters. Thus, the best amounts of control factors are those that maximise S/N ratios. SNR values are logarithmic functions of output quality preferences. "Orthogonal Arrays" are the basis for the tests used to discover the best levels, which are balanced with regard to all control factors while still being minimal in number. This suggests that the resources (materials and time) required for the trials are also low. STATIC and DYNAMIC are two of Taguchi's two categories of problems. Dynamic problems have a SIGNAL factor, whereas static problems do not. Static difficulties are optimised by comparing three Signal-to-Noise ratios: the lower, the better, and the greater, the better. In Dynamic issues, Slope and Linearity Signal-to-Noise Ratios are employed to optimise. This approach to process/product optimization is based on eight phases that involve planning, carrying out, and analysing the results of matrix experiments to determine the best amounts of control parameters. The Taguchi Method Even with noisy inputs, the main objective is to maintain the output variance as low as possible. In this way, processes and products are designed to be impervious to errors.

Table 5.1: Factors and Levels

Factors	Duty Cycle	Road Inclination (Degrees)	Wind velocity (m/s)
1	0.3	0	25
2	0.6	20	50
3	0.9	40	75

Table 5.2: Taguchi L27 orthogonal array – Simulation and Results

SI.NO	Input			Output					
	Duty Cycle	Wind Velocity (m/s)	Road Inclination (Deg)	Vehicle Velocity (m/s)		Three-Phase Current (A)		Three-phase Voltage (V)	
				Max Peak	Time (Sec)	Max Peak	Time (Sec)	Max peak	Time (Sec)
1	0.3	25	0	8.45	39.60	213.7	42.86	21.45	44.73
2	0.3	25	20	37.57	26.13	1189	22.71	317.90	22.71
3	0.3	25	40	71.57	46.92	7724	29.32	1676	40.254
4	0.3	50	0	27.20	27.03	799.2	27.10	157.40	27.10
5	0.3	50	20	75.64	44.06	9288	38.18	2289	38.18
6	0.3	50	40	80.60	28.63	13130	21.96	3014	24.73
7	0.3	75	0	43.89	10.26	1999	9.73	591.4	9.73
8	0.3	75	20	79.53	44.90	11910	30.99	2494	27.13
9	0.3	75	40	84.92	33.08	20960	33.49	3739	33.48
10	0.6	25	0	10.03	43.08	294.8	38.87	26.52	43.75
11	0.6	25	20	37.57	48.54	1167	23.00	336.90	23.00
12	0.6	25	40	71.52	42.27	14240	21.16	2011	43.27
13	0.6	50	0	25.31	27.29	787.7	17.28	154.70	26.74
14	0.6	50	20	44.00	47.75	2008	14.49	573.50	13.41
15	0.6	50	40	80.06	34.70	18320	47.56	3041	34.57
16	0.6	75	0	43.88	41.89	1915	9.03	527.20	9.16
17	0.6	75	20	79.19	38.52	16980	44.72	2850	41.59
18	0.6	75	40	84.67	22.55	23610	21.44	4169	17.03

19	0.9	25	0	10.63	49.73	374.0	49.92	29.24	45.15
20	0.9	25	20	39.41	31.27	1287	26.94	368.90	27.65
21	0.9	25	40	71.08	28.64	19490	25.55	2903	25.55
22	0.9	50	0	25.71	27.95	784.0	20.29	143.20	27.69
23	0.9	50	20	44.00	19.93	1927	15.24	585.10	15.23
24	0.9	50	40	79.23	17.12	28520	14.65	4225	17.11
25	0.9	75	0	43.88	14.37	1917	10.03	583.20	10.02
26	0.9	75	20	78.94	14.52	29210	13.89	3731	11.84
27	0.9	75	40	80.70	9.71	28190	8.80	3238	8.80

Table 5.3: Taguchi Response table

Response	Levels	Duty Cycle	Wind velocity (m/s)	Road Inclination (Degrees)
Velocity	1	56.59	39.75	26.55
	2	44.55	53.52	57.31
	3	52.62	68.84	78.26
Phase current	1	7468.1	5108.87	1009.45
	2	8813.61	8396.02	8329.55
	3	12411.07	15187.88	19353.77
Voltage	1	1588.90	854.54	248.25
	2	1521.09	1575.87	1505.14
	3	1756.29	2435.86	3112.88

Taguchi Optimisation Graphs

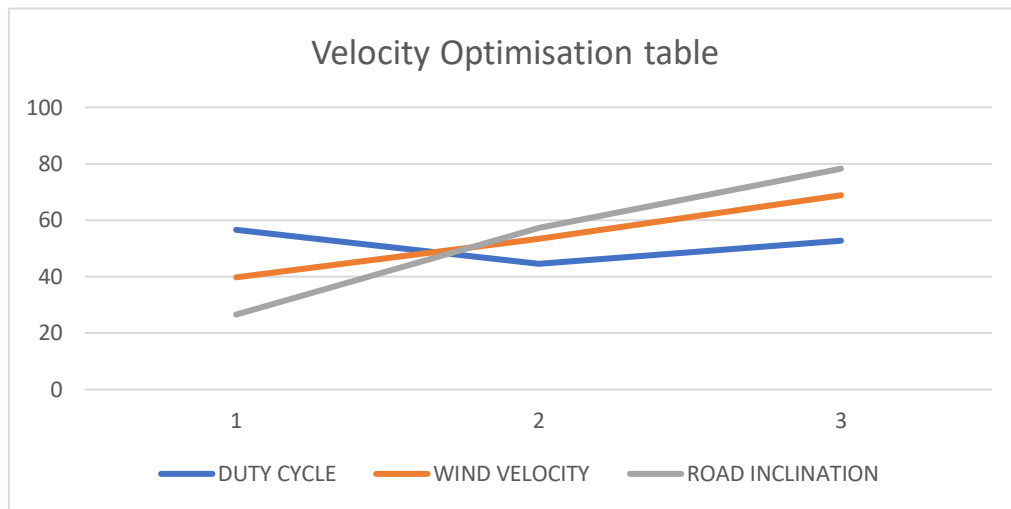


Fig: 5.1 : Taguchi Optimization graph (velocity optimization table)

The above plot demonstrates the velocity Optimization of the vehicle. We can observe that the duty cycle is approaching a constant trajectory and comparatively more than wind velocity and road inclination. According to the graph, the change in the duty cycle with respect to time does not affect the current required much like Wind Velocity and Road Inclination. The second drastic change in the current is caused by the wind velocity because it requires more velocity for the vehicle in case of the opposing wind drag. The first and high drastic change in velocity is caused due to the change in Road Inclination, this may be caused by the opposing gravitational force resisting the climb of the vehicle over inclination. In this plot we conclude, road inclination is the most influencing factor compared to duty cycle and wind velocity because if the inclination is high, the BLDC motor consumes more power.

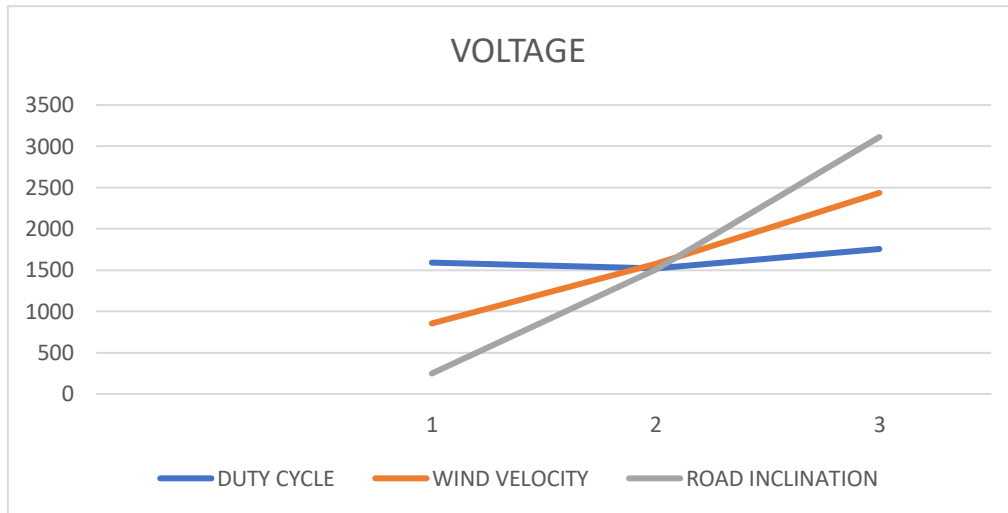


Fig: 5.2 : Taguchi Optimization graph(Three-phase voltage)

The above plot demonstrates the Three-phase voltage Optimization of the vehicle. We can observe that the duty cycle is approaching a constant trajectory and comparatively more than wind velocity and road inclination. According to the graph, the change in the duty cycle with respect to time does not affect the voltage required much like Wind Velocity and Road Inclination. The second drastic change in the voltage is caused by the wind velocity because it requires more voltage for the vehicle in case of the opposing wind drag. The first and high drastic change in voltage is caused due to the change in Road Inclination, this may be caused by the opposing gravitational force resisting the climb of the vehicle over inclination. In this plot we conclude, road inclination is the most influencing factor compared to duty cycle and wind velocity because if the inclination is high, the BLDC motor consumes more power.

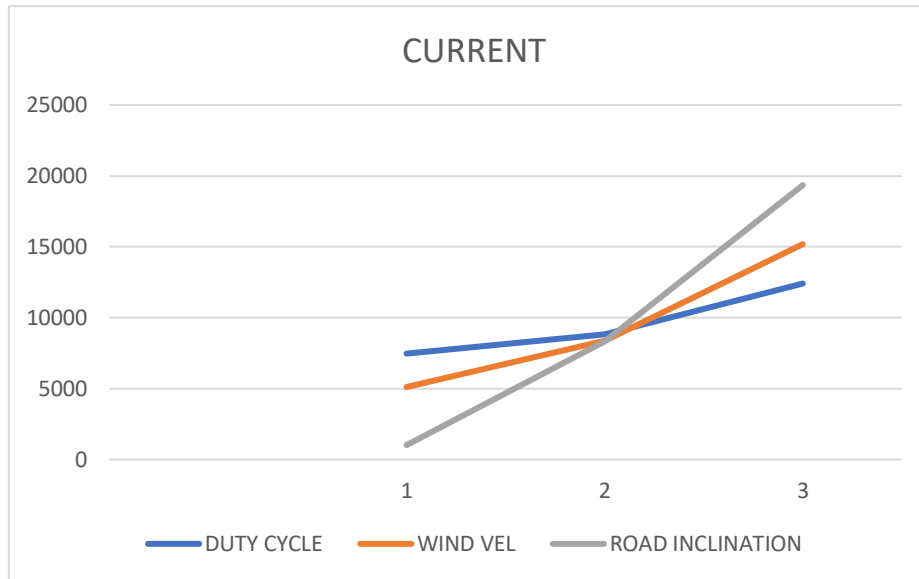


Fig: 5.3 : Taguchi Optimization graph(Three-phase current)

The above plot demonstrates the Three-phase Current Optimization of the vehicle. We can observe that the duty cycle is approaching a constant trajectory and comparatively more than wind velocity and road inclination. According to the graph, the change in the duty cycle with respect to time does not affect the current required much like Wind Velocity and Road Inclination. The second drastic change in the current is caused by the wind velocity because it requires more current for the vehicle in case of the opposing wind drag. The first and high drastic change in current is caused due to the change in Road Inclination, this may be caused by the opposing gravitational force resisting the climb of the vehicle over inclination. In this plot we conclude, road inclination is the most influencing factor compared to duty cycle and wind velocity because if the inclination is high, the BLDC motor consumes more power.

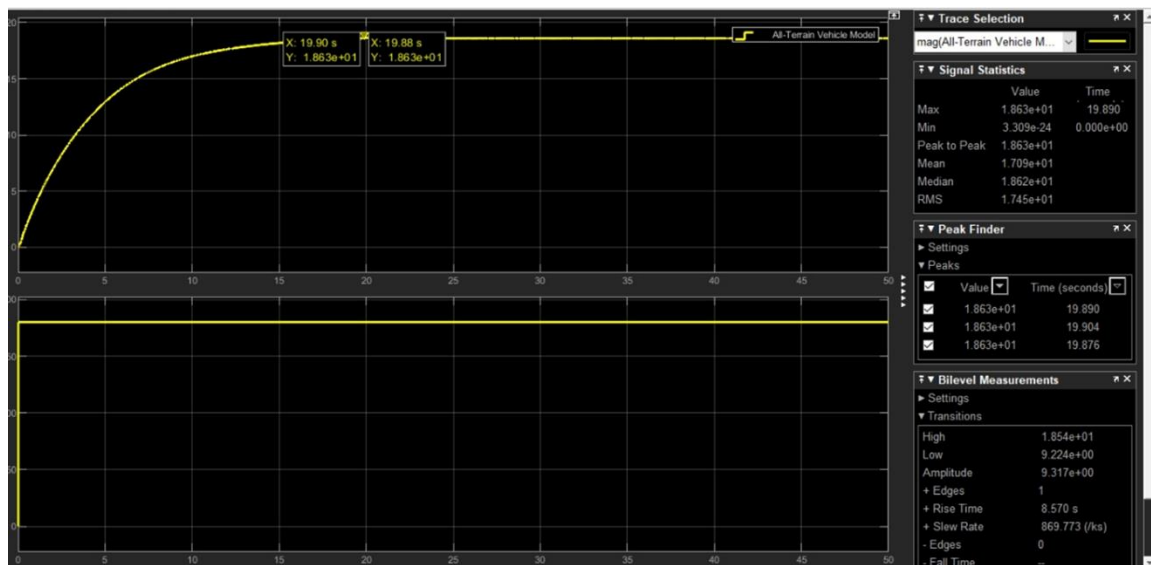


Fig: 5.4 : Vehicle velocity

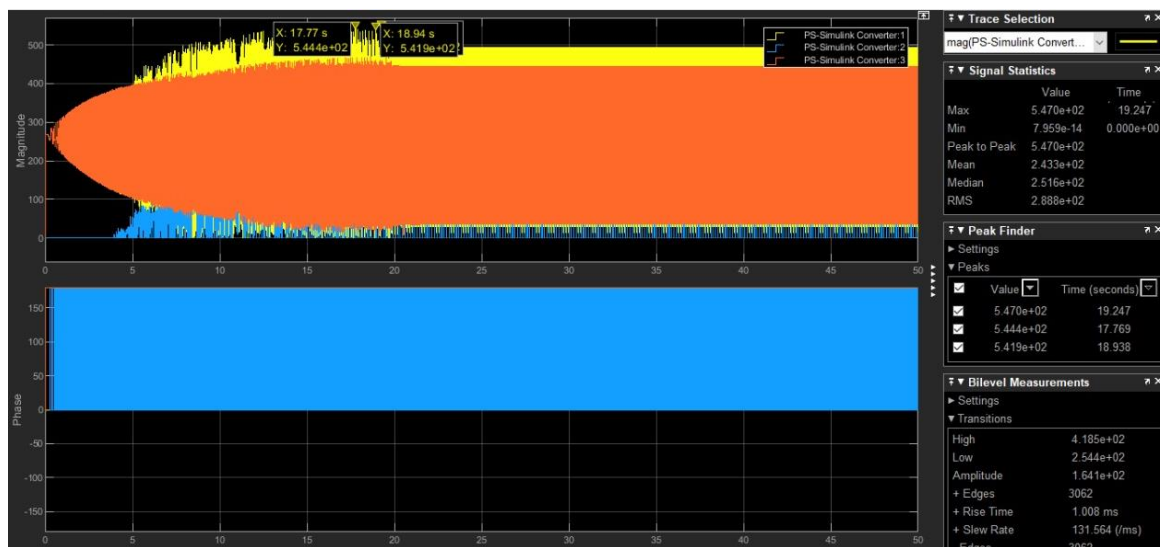


Fig: 5.5 : Three-phase current

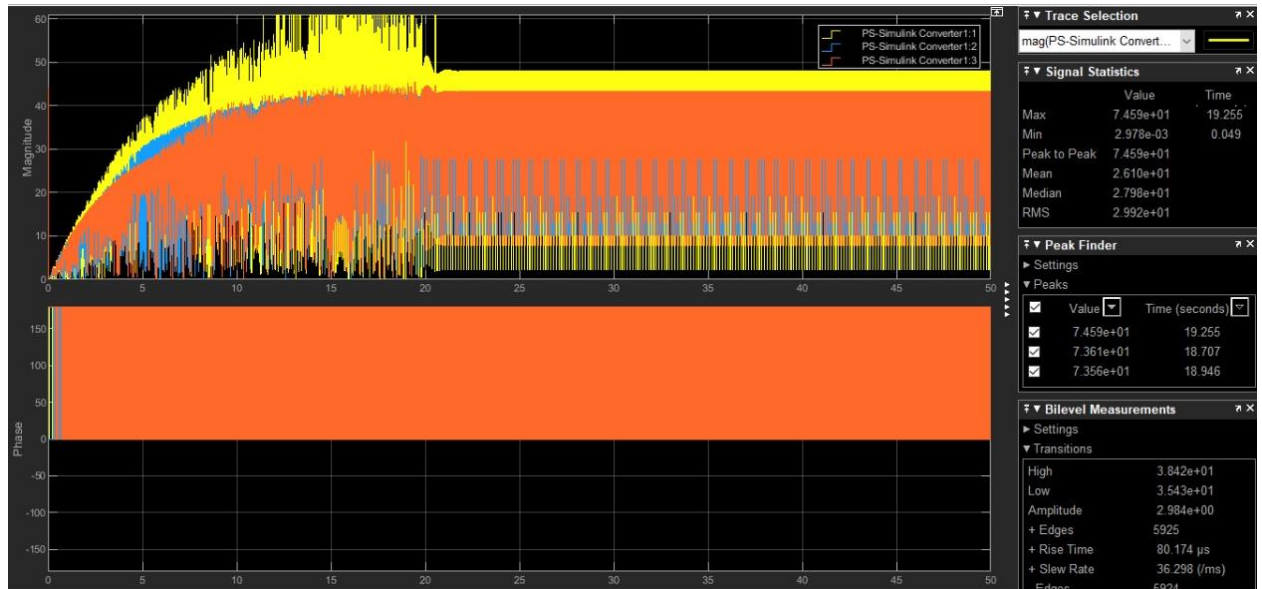


Fig: 5.6 : Three-phase voltage

CHAPTER 6

SUMMARY AND CONCLUSION

A square model of the All terrain vehicle was modelled using MATLAB-SIMULINK. Power was supplied through a motor and the values for motor and tyres were taken from the MATLAB library or default values were employed. Vehicle behaviour was analyzed through different vehicle result boundaries. The components of the electric vehicle, transmission, battery were modelled to determine the type of velocity that suits the model.

Simulation was executed through MATLAB code and Simulink blocks. The vehicle was simulated for different duty cycles, wind velocity and road inclination and the results were tabulated. The response of vehicle velocity, Current and voltage for the different input parameters were studied and analysed. Taguchi Response table was used to analyse the effects of the input parameters on the output responses. It could be found that road inclination had major effect on all the output responses, whereas the duty cycle and velocity had lesser magnitude of effect. When the road inclination is high, the BLDC motor consumes more power and hence results in this drastic change.

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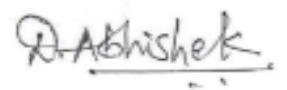
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Simulation of All-Terrain Electric Vehicle Using MATLAB Simulink

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ABSTRACT

Off-road vehicles are one of the most prevalent vehicles, that have been developed for quite some time in the mid-1970s, but their use has grown since then. An all-terrain electric vehicle may be used for on- and off-road mobility, as well as for homestead, valley rides, and slope climbing. The distinct and unique concept contains new steering knuckles, a bunch board, ability turnover assurance, driver ergonomics, and private components. An all-terrain vehicle (ATV), sometimes known as a quad bicycle or just a quad, is a light utility vehicle (LUV) with a seat for the administrator and handlebars for managing control that rides on low-pressure tyres. It is now being researched to deal with a wider range of landscapes than others. It is developed to deal with a wide variety of terrain than most other vehicles. The rider sits and operates these vehicles in the same way as a cruiser do, but the extra wheels provide more security at slower speeds. Despite the fact that most are equipped with three or four wheels, six-wheel variants are available for certain uses. In this project a square model of an ATV activated by a burning motor will be fabricated and recreation will be completed. The information values for different parts like motor, tires, stopping mechanism, and so forth are either taken from the MathWorks site or default values are utilized. At long last, different result boundaries of the vehicle will be considered to quantify the vehicle conduct. In this paper, we present a Matlab/Simulink model for electric all-terrain vehicles (ATVs). We model the vehicle elements, transmission execution, and battery of the EVs to gain the power requirements of the battery and to later conclude the best kinds of velocity to use for a variety of applications. The reenactments are performed through the coordination of the MATLAB code and Simulink blocks. The speed of the vehicle and its distance made a trip compare to genuine driving cycles and force varieties of an EV. The additional worth of this model is that it reproduces the streamlined drag, direct speed increase, and moving obstruction powers where they are displayed.

1. INTRODUCTION

An electric vehicle (EV) is powered by an electric motor instead of an IC engine. The battery is used to generate power for the electric motor. Electric vehicle layouts the opportunity to link the renewable power and low-carbon transport sectors. The usage of electric vehicles has increased enormously because high fuel rate in the country. Automobiles are mostly used for on-road transportation. The all-terrain vehicle is a newer segment of a small vehicle that is popular in North America. This vehicle was a simple three-wheeled vehicle powered by a small 90cc ICE. The vehicle was designed to be used for recreational purposes at first. The continued development of three-wheeled vehicles eventually led to the four-wheeled vehicles we know today. High-performance and nimble vehicles are utilized in a range of sectors, including farming, forestry, natural resource research, law enforcement, and peacekeeping, in addition to recreation. however, this preliminary investigation is carried out to determine the vehicle's initial power and torque requirements.

The transition from a gasoline-powered all-terrain vehicle (ATV) to an electric ATV is described in this research paper [1]. Preliminary examinations are carried out to explore the vehicle's initial power and torque requirements. The mechanical load model is developed and compared to the data given by the manufacturer. Using an electromagnetic transient simulation tool, the load model is integrated with an electrical drive and motor simulation (PSCAD). Simulation result, the primary components, an electric traction motor, batteries, and a custom motor drive, are collected, and a vehicle prototype is integrated. The result of both the simulation and the prototype were compared and analyzed.

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