Design, Analysis, Simulation, Implementation and Testing of 4WD Electric Powertrain of the Electric – Baja All-Terrain Vehicle (E-ATV)

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Abstract

This paper discusses about the complete electric powertrain of the electric ATV (All-Terrain Vehicle) that is built by an SAE collegiate team. The powertrain has two subgroups namely mechanical powertrain and electrical powertrain. Electrical powertrain focuses on selection of Battery, Motor, Motor controller, DC-DC converter and designing of Dashboard indicators, Main Controlling circuits, electrical safety systems like Accumulator Isolation Relays, protection fuses, Miniature Circuit Brakers (MCB) and HV cut-off switch. This paper aims to discuss all about Electric powertrain.

Keywords - Powertrain, Motor, Battery pack, Control circuit, BMS, Charging, Insulation, HV, GLV, DFMEA, DVP.

Introduction

The team Phoenix Racing was started in the year 2012. It designs, fabricates, manufactures, analyses, tests an electric All-Terrain vehicle. The team participates with the vehicle, in various ATV racing events like E Baja conducted by SAE India, MegaATV, FMAE BAJA. The team comprises of 4 main sub-wings namely Powertrain, Suspension & Steering, Roll cage Brakes & Unsprung. The team starts its work by holding objectives.

The team collaborates with all the sub-wings and designs the buggy with some objectives. The prime objective to be achieved by powertrain department is improved traction and control by implementing 4WD (4-wheel Drivetrain). Improved traction is attained by the construction of powertrain [4]. The 4WD vehicle has the capability of splitting equal torque to all wheels [3]. The Performance targets set are improved Acceleration, Better Gradeability, Maximum speed, efficient Torque. The design of components and selection of OEM products starts with powertrain calculations. The components are selected based on their performance, safety, standards, cost and ease of availability. The electrical components and system are fitted as per rulebook guidelines. Prime consideration is given to safety.

The sub-system is developed with DVP and D/P FMEA plans and all the components and system were verified using software as well as real world testing. The developed powertrain architecture is integrated and the complete vehicle is tested. Various problems were identified during fabrication and testing phase and were solved using best and correct solutions. The developed vehicle has also participated in BAJA SAE India 2023 event and got remarkable positions.

2. Components of E – Powertrain

- Battery pack
- DC – DC Converter
- Electric motor
- Motor controller
- Battery management system
- Control panel
- GLV ancillary systems (lightings, alarms)

3. Mathematical modelling

The powertrain department starts designing with Mathematical modelling. Basic achievable parameters like Acceleration, gradeability angle, mass of the vehicle, etc. are predetermined and consecutive calculations like acceleration, max. tractive effort, Gear ratios, gear profile are calculated [10]. The High Voltage (HV) components like motor, battery pack are selected based on the powertrain calculations.

3.1 Total Tractive Effort

Gross mass of the vehicle = 310 Kg

Gross weight = 3,041 N

Tire static radius = 279.4 mm

Assuming transmission system efficiency as 0.71,

Frontal area = Maximum width * Maximum height = 1.6 m^2

Co-efficient of friction:

For concrete = 1

For Dry sand = 0.65

Co-efficient of rolling resistance:

For concrete = 0.014

For dry sand = 0.05

Rolling resistance = Gross weight * Co-efficient of rolling resistance (Dry sand)

= 3,041 * 0.05 = 152.05 N

Aerodynamic resistance = (1/2) * Air density * $(velocity)^2$ * Frontal area * Aerodynamic drag co-efficient

= (1/2) * 1.12 * $(16.66)^2$ * (1.6) * (0.44) = 13.136 N

Grade resistance = Gross weight * sin α

= 3041 * sin (26.56) = 1359.7 N

Total Tractive effort = Rolling Resistance + Aerodynamic resistance + Grade Resistance

= 152.05 N + 13.136 N + 1359.7 N = 1524.85 N

Considering efficiency, (P_{out} / P_{in}),

$\eta_{tranS} = \eta_{CVT} + \eta_{Gearbox} + \eta_{Propeller\ shaft} + \eta_{Differential} + \eta_{Drive\ shaft}$

➔ V = 8 km / hr. @ 50 % gradeability

Max Tractive effort at 50% gradeability = T_m

= Co-efficient of friction of dry sand * Gross weight of the vehicle * cos α

= 0.65 * 3041 N * cos (26.56) = 1768.047 N.

Max Tractive effort at 50% gradeability is less than the T_m.

Hence, No Slip occurs.

Torque produced at wheels = T.T.E. * Tire static radius (in meter)

= 1524.85 N * 0.2695 m = 410.947 N.

3.2 Acceleration

A car's ability to accelerate swiftly from a stop or the time it takes to do so is also referred to in the context of vehicles. Low gear is always used for acceleration and negotiating hills since the loss of speed is greater there and the pulling force at the wheels is largest. The Torque required is assumed as 600 Nm.

T_m = T (design torque) / r (tire static radius) = 600/0.2794

= 2147.45 N

Where, T_m = Max. tractive effort for design torque

Traction force = T_m – Total Tractive Effort (T.T.E)

= 2147.45 N – 1524.85 N = 622.6 N

Acceleration, a = Friction force / Mass of the vehicle

= 2.008 m / s^2.

Thus, the powertrain calculations are done and final points are summarized as shown in below table in order to pursue OEM main powertrain components.

3.3 Machine and selection

Energy required for 1 second = T.T.E. * v = 3000 Watts (W)

W.K.T. Motor rated power, P = 5 kW = 5000 W

Thus, the machine with about 5 kW is selected as the electric motor for the vehicle.

3.4 Battery pack selection

Since the battery voltage and capacity should not exceed above 60 V and 120 Ah, the battery pack is selected according to that. The pack is also IEC 60529 IP67 standard satisfying as per the rulebook. (C.3.1)

4. Electric Powertrain architecture

The electric powertrain architecture is derived from the complete powertrain architecture. Various components are interconnected in a sequential manner in order to make complete drivetrain. The following flowchart explains that in a better way.

Transmission Unit data		
Net Transmission Ratio	Max	Min
	33.15	7.65
CVT Model	Gaged Gx9	
CVT Ratio	Low	High
	3.9: 1	0.9: 1
Engagement Speed	900 rpm	
Shift Speed	3800 rpm	
Gearbox	2 Stage Red	
Gearbox Ratio	8:1	
Drive Shaft	Tripod Joint	
Half Shaft Material	AISI 1050	
OD	19 mm	
Plunge length	40 mm	
Articulation Angle	32 degrees	
Radius of Gyration	0.2 m	

Table.1.Powertrain components and system parameters specifications

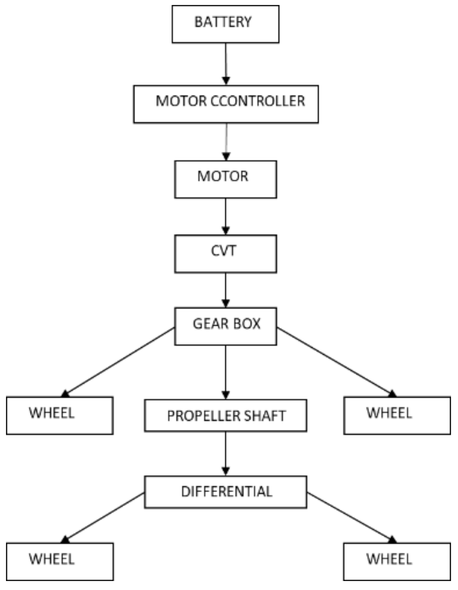


Fig.1. Flowchart of power flow of the E – Powertrain

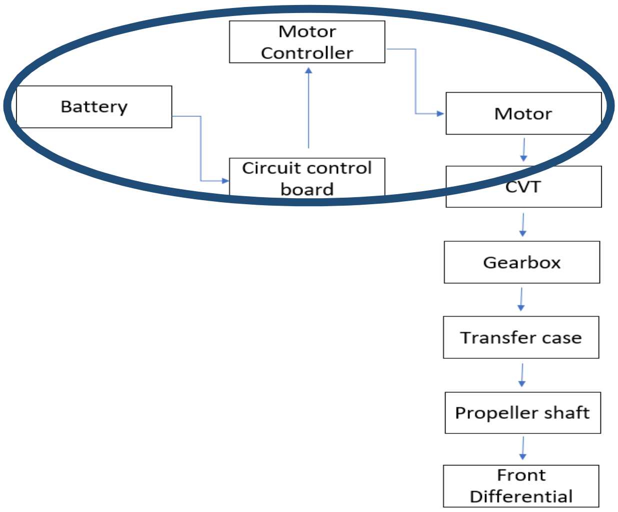


Fig.2. Power flow and position of Electrical powertrain in the flow

5. Components of E – Powertrain

- Battery pack
- DC – DC Converter
- Electric motor
- Motor controller
- Battery management system
- Main control unit
- GLV ancillary systems (lightings, alarms)

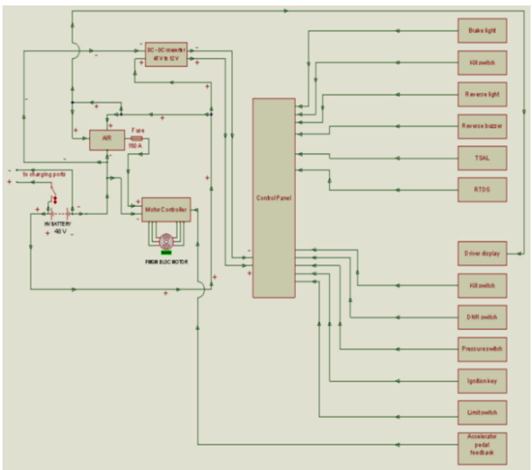


Fig.3. Schematic of current year's electric powertrain architecture drawn in proteus

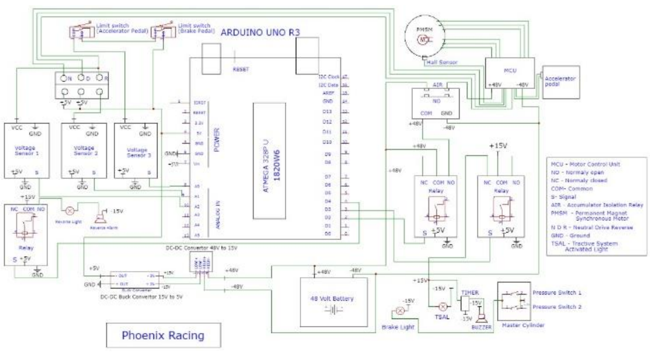


Fig.4. New modified circuit diagram which is yet to build next year drawn in EasyEDA

6. High Voltage Tractive system

It deals with High Voltage system components namely HV Battery and Electric Motor. The tractive system of the vehicle is defined as every part that is electrically connected to the motor(s) and tractive system Accumulator(s). The Voltage between any two terminals of the tractive system in the vehicle shall not exceed 60V DC in any condition. All components in the tractive system must be rated for the maximum tractive system voltage. The tractive system Accumulator(s) is defined as all the battery cells that store the electrical energy to be used by the tractive system along with the corresponding contactor, fuse, and battery management systems/solutions.

The tractive system motor(s) must be connected to the Accumulator(s) through a motor controller (Traction Controller). Bypassing the control system and connecting the tractive batteries directly to the motor(s) is strictly prohibited. [1].

7. Battery Pack

The energy required to power the vehicle is stored in the battery pack, which is made up of many cells. Direct current output is provided by a battery pack. The bulk of portable consumer devices currently employ lithium-ion batteries due to their high energy density per mass compared to other electrical energy storage solutions. They also work well at high temperatures, have a high power-to-weight ratio, are highly energy-efficient, and discharge themselves slowly. The battery pack is bought as OEM from Eifer Megacorp. It is of NMC chemistry type and has 48 V 120 Ah capacity.

Accumulator	
Accumulator series Configuration	13
Accumulator Parallel Configuration	24
Maximum Voltage (V)	54.6
Nominal Voltage (V)	46.8
Cutoff Voltage (V)	35.75
Nominal Capacity (Ah)	120
Approximate Weight (kg)	40
Dimensional (Length x Width x Height in mm)	428*428*178
Max Continuous Discharge Current (A)	180
Max Instantaneous Discharge Current (A)	200
Charge Voltage (V)	54.6
Operating Temperature range (°C)	(-20) -(55)
Battery Cooling Type	Nature Cooling
IP Rating	67
Vendor details	Eifer Megacorp Pvt Ltd
Charger	48 V 30 A
Configuration	13 s 24 p

Table.2. Accumulator configurations

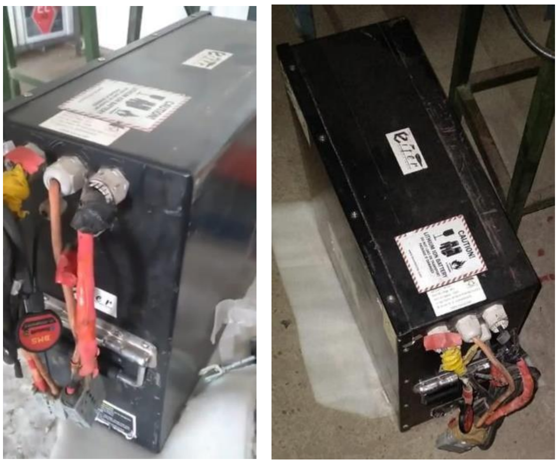


Fig.5. Accumulator pictures and Specifications

Every time, for designing and fabrication of the roll cage (Chassis), a battery pack prototype is made using cardboard in order to check the clearance as per rulebook. The roll cage to accumulator clearance is considered for swapping process and designed according to that [1].

Fig.6. Battery prototype

7.1 Mounting of battery pack

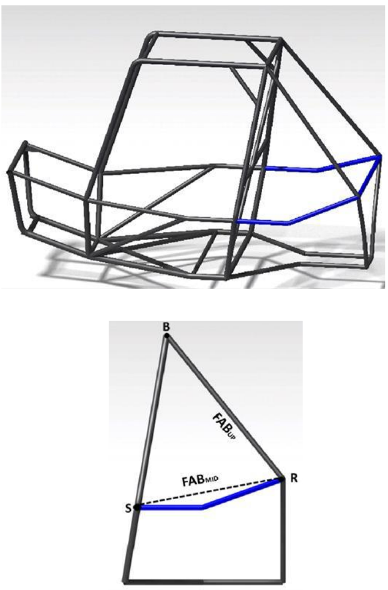


Fig.7. Position of battery pack on roll cage

The battery pack is mount on the area above the S-R plane such that path of battery removal during battery swapping should be easier and accessible both in horizontal and vertical direction of movement.

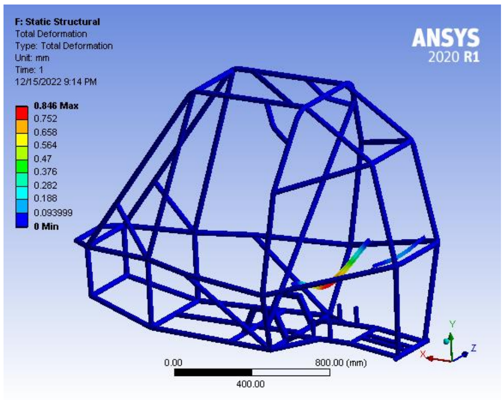
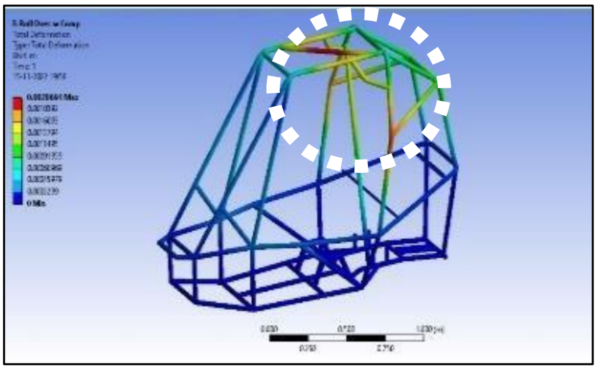


Fig.8. a. Battery mounting "L" brackets load analysis



FOS	Equivalent Stress (MPa)	Total Deflection (mm)
1.4269	3.225 x 10⁸	0.00058537

Fig.8. b. Roll over impact analysis

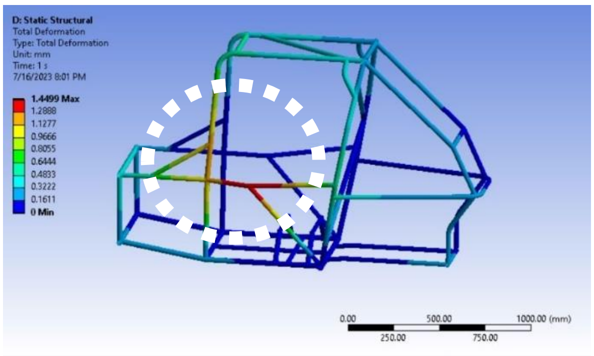


Fig.8. c. Cabin force impact analysis

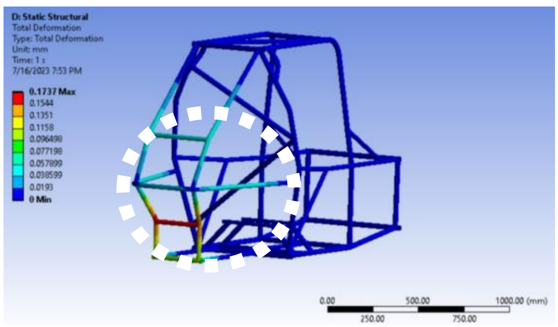


Fig.8. d. Rear Motor impact analysis

The Battery and Electrical component mounting members are analyzed with a significant load impact to test their rigidity and safety such that the electricals re safely mounted.

The battery pack is bought as OEM from Eifer Megacorp of India as per rulebook and design requirements. The laboratory test for checking standards is done. One battery pack is having nominal voltage of 48 V and another one is of 52 V.

STC LAB STANDARD TESTING & COMPLIANCE (STC LAB)
Tel : 0129-4321765 | Email : info@stclab.in | website : www.stclab.in

TEST REPORT

TEST REPORT AS PER: IS/IEC 60529:2001

Page No.: 1of 4

ULR No.:-	TC962922000000059F	Group/ Discipline:	ELECTRICAL/ENVIRONMENTAL TEST FACILITY
Test Report No.	STC/Test/20220228001		Date of Issue: 15/03/2022

Name & Address of Customer:	EIFER MEGACORP PRIVATED LIMITED CHINTALAPUDI, 11-112, SARDA THEATRE NEAR OLD BUS STAND, West Godavari, Andhra Pradesh, 534460	
Name & Address of Manufacturer (If required):	–	
Customer Ref. & Date:	Nil	W.O. No.: 20220228001
Date of Sample Receipt: 28/02/2022	Start of Test Date: 28/02/2022	End of Test Date: 03/03/2022

PART A - PARTICULARS OF THE SAMPLE SUBMITTED

Sample description	Metal Box(419*418*173)
Grade/ variety/ type/ class/ size etc.	48V, 120Ah (13s 24p)
Declared values, if any	IP67
Code no., BIS seal and IO's sign, if any	Nil
Batch no., date of manufacture and Brand Name	Manufacture: "EIFER MEGACORP PRIVATED LIMITED"
Model	–
Quantity	01 Nos.
Condition of the sample	OK
Reference specification (s)	IS/IEC 60529:2001
Environmental conditions	Temperature (25±10)°C & Relative Humidity(45-75)%

PART-B: SUPPLEMENTARY INFORMATION

1. If an Item is tested, acknowledging deviations from specified conditions as requested by customers, the results may be affected due to this deviation.
2. Details of the drawings, graphs, tables, sketches or photographs as referred in the test report, if any:
3. The standards/ Instruments used are maintained in accordance with ISO / IEC 17025 and are traceable to National and International Standards

Notes:

1. This report is not to be reproduced except in full/partial without approval of the laboratory in writing.
2. This report refers only to the particular sample detailed above.
3. The results reported in this Test report are valid at the time of and under the stipulated conditions of measurement.

Tested by	Approved by
(Esha Tyagi/Testing Engineer)	(Shivendra Kumar/Technical Manager)

Format No. - STCLAB/F/EL/06

Address : #14/7, Parmeshwari Colony, Mathura Road, Faridabad (Haryana) - 121008, India

Fig.9. battery test report

Cells	
Cell Make / Model / Style	HLY/Lithium/26650
Cell Chemistry (LFP, NCA, LTO etc.,)	NMC
Cell nominal capacity (mAh)	5000
Maximum Voltage (V)	4.2
Nominal Voltage (V)	3.6
Minimum Voltage (V)	2.75
Maximum peak discharge current (30s) (A)	15
Maximum continuous discharge current (A)	10
Maximum peak charge current (<80% SoC) (30s) (A)	15
Maximum continuous charge current	2.5
Maximum Cell Cut-Off Temperature (discharging) (°C)	65
Maximum Cell Cut-Off Temperature (charging) (°C)	60
Vendor details (if any)	Eifer Megacorp Pvt Ltd

Table.3. Battery cells configurations

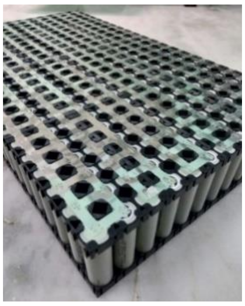
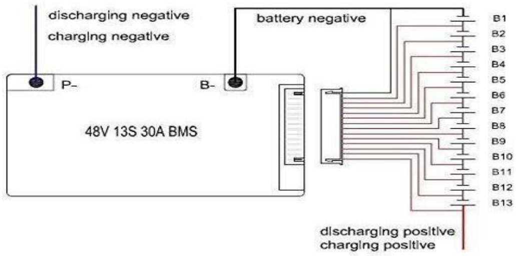


Fig.10. battery cells arrangement

7.2 Battery Management System (BMS)

The Daly BMS is fixed as OEM and is fitted inside the battery pack enclosure itself. The BMS satisfies all the standards specified in rulebook clause C.4.6. the battery BMS data is analysed using the smartBMS app which communicates with the BMS using Bluetooth communication.



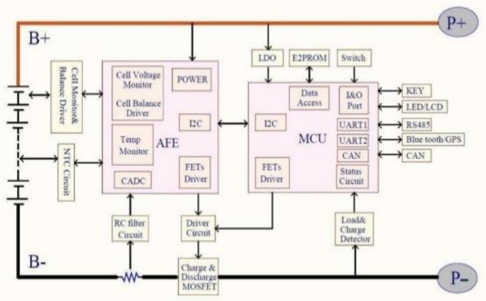


Fig.11. BMS circuit diagram

Fig.12. Daly BMS

The battery parameters are measured using BMS tag and smartBMS app in mobile phone using Bluetooth communication.

Fig.13. Daly BMS tag used for transmitting BMS data to mobile phone using Bluetooth

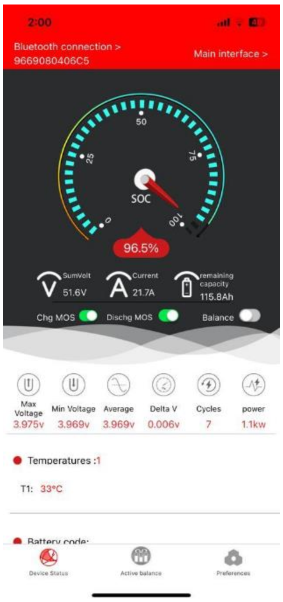


Fig.14. SmartBMS app

BMS		
	Details	Specifications
Discharge	Maximal Continuous Discharging current (A)	180
	Peak Discharging Current (A)	200
	Over Current Protection Current (A)	200
Charge	Charging Voltage (V)	54.6
	Charging Current (A)	100
Over charge protection	Over Charge Detection Voltage (V)	4.25
	Over Charge Detection Delay Time (seconds)	1
	Over Charger Release Voltage (V)	4.15
	Cell balancing Detection Voltage (V)	3.8
	Cell balancing Release Voltage (V)	4.25
Cell balancing	Cell balancing Current (A)	2
	Over Discharge Detection Voltage (V)	2.7
Over discharge protection	Over Discharge Detection Delay Time (seconds)	1
	Over Discharge Release Voltage (V)	2.8
	Over Current Detection Voltage (V)	2.75
Over current protection	Over Current Detection Delay Time (seconds)	1
	Over Current Protection Condition	Off load
	Detection Condition	Off load
Short Protection	Detection Delay Time (seconds)	5000 µs
	Release Condition	Off load
Over - Temperature Protection Cut-Off (°C)		60
Vendor details		Eifer Megacorp Pvt Ltd

Table.4. Battery Management System details

8. Charger

The Charger is also bought as OEM from Eifer Megacorp. Charger specifications are given below. A unique charging station area is allotted for charging the battery as per standards. The charging environment at garage is implemented as per charging safety standards mentioned in rulebook C.4.7 & C.4.8.

Parameter	Range	
Model	ES-4835	ES-8325
Battery Pack Type	Li-Ion LiFePO4 or NCM 13 to 16 Cell Series Lead Acid – 3/4 Series Flooded or VRLA	Li-Ion LiFePO4 or NCM 19 to 23 Cell Series Lead Acid – 5 Series Flooded or VRLA
CHARGING VOLTAGE	48V to 65V ± 0.5V (Configurable in 0.5V steps)	68V to 84V ± 0.5V (Configurable in 0.5V steps)
CHARGING CURRENT	15A - 35A ± 1A (Configurable in 1A steps)	10A - 25A ± 1A (Configurable in 1A steps)
CHARGE PROFILE	Li-Ion: Three Stages – CC, CV, Charge Termination with Current Threshold and Timer. Lead Acid: Four Stage – Bulk CC, Absorption CC, Absorption CV and Float charge	
MAINS OPREATING RANGE	120VAC±10V -280VAC±10V, 40 Hz TO 60 Hz	
INPUT POWER FACTOR	Active PF correction, >0.95	
EFFICIENCY	89% Typical at nominal input	90% Typical at nominal input
LCD Display Parameters	SCREEN1 – Charger Bar Graph, Elapsed Time – Instantaneous Charging Current and Battery Voltage	
	SCREEN2 – Selected Battery Type, Set CC Current, Set CV Voltage	
	SCREEN3 – Mains Voltage and Frequency, Ambient Temperature (optional)	
LED INDICATIONS	3 LEDs – Green – Charging On, Yellow – Charging Stopped, Red - Fault	
AUDIO INDICATIONS (Buzzer)	Power On, Charging Start or Stop – Short Beeps Battery Charge Completion – Interminent beeps upto 20minutes. Mains Failure or any Faults - Long Beeps	
REVERSE BATTERY PROTECTION	Electronically Protected – Charger will not start unless battery is connected in correct polarity.	
MAINS VOLTAGE PROTECTION	Withstand up to 320V AC RMS with Surge Protection.	
MAINS OVER CURRENT PROTECTION	By FUSE, in case of abnormal condition	
COOLING SYSTEM	Forced Air Cooled	
THERMAL PROTECTION	Electronically protected with internal temperature sensor.	
CHARGER OPERATING TEMPRATURE	0°C TO 45°C	
Battery Cable	3mts 6sqmm with Anderson Type 50A Connector. 50A Terminal Block.	
Mains Cable	1.8mts 1.5sqmm 3Core Cable with 16A molded Plug.	
HUMIDITY	95% RH Non-Condensing	
ENCLOSURE	Powder coated sheet metal cabinet	
NET WEIGHT	6.0 kgs	

Fig.15. Charger Specifications and Charger picture

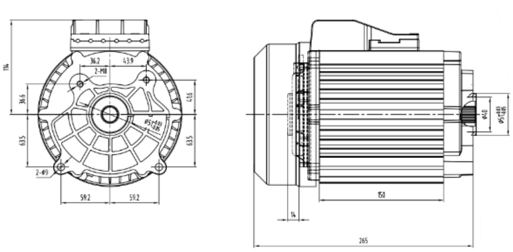
Fig.16. Battery charging setup at garage

9. Electric Motor

The motor is chosen as Permanent Magnet Synchronous Brushless DC Motor (PMSM) for better controlling and traction on any type of surface. It is brought from Datai corporation. It has 6 phases and the coils are energized according to hall sensor feedback signal and throttle input signal.

Motor			
Make / Model	DATAI		
Operating Voltage (V)	48V		
Cont. Rated Power (kW) @ RPM	5kW	@	3600 RPM
Max Peak Power (kW) @ RPM	7.2kW	@	2700 RPM
Rated Speed (RPM)	3900 RPM		
Maximum Speed (RPM)	4500 RPM		
Cont. Rated Torque (Nm) @ RPM	25Nm	@	2700RPM
Max Peak Torque (Nm) @ RPM	75Nm	@	300RPM
Cooling Type	AIR COOLING		
Cooling system is powered of	connected with motor shaft		
Age of the Motor if reused (in Years)	0		
Operating Temperature range (°C)	0-50		
Vendor details	Eifer Megacorp Pvt Ltd		

Table.5. Motor Configuration



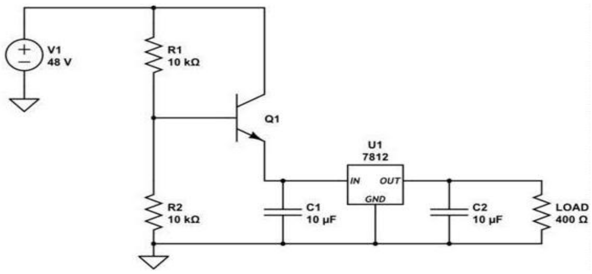
146-95-100.8

PMSM CONFIGURATION	
Voltage	48 V
Max Torque	75 @300 RPM
Rated / Peak Power	5 / 7.2 KW
Rated / Peak Speed	3900 / 4500rpm
Rated / Peak Torque	25 / 75 Nm
Water Resistant	IP67

Fig.17. Picture and Engineering diagram of Motor

10. DC – DC Converter

A direct current (DC) to direct current (DC) converter is a circuit or electrical device that alters the voltage level of a direct current (DC) source. It's a type of electromagnetic power converter. Tiny batteries have very little power, whereas high-voltage power transfer has a lot. DC-to-DC converter circuitry is often used to adjust the output voltage. One exception is high-efficiency LED power sources, which are a form of DC-to-DC converter that manages the current through the LEDs. Another option is to employ simple charge pumps, which can raise the output voltage by two or three times.



DC-DC Converter	
Type	Lsolated type
Input rated voltage(V)	48
Input voltage range(V)	40-90
Efflciency(%)	90
Output voltage(V)	12
Output current(A)	15
Output rated power(W)	180
Output peak power(W)	240
Voltage regulation(%)	±10%
Load regulation(%)	±10%
Ripple (full load test)	300mv
No-load current(A)	0.01A
Working Temperature(℃)	.-25℃+85℃
Ip Rating	IP65
Protections(Over-volt, Under-volt etc.,)	1.temperature protection 95 ℃ 2.Overcurrent protection 3.Short-circuit protection 4.Overvoltage protection
Fuse rating(A)	15A

Fig.18. Picture, circuit diagram, specifications of DC – DC converter

11. Motor Controller

A motor controller is a piece of equipment, or group of equipment, that has the ability to regulate how an electric motor operates in accordance with established rules. A motor controller makes it possible to start and stop the motor automatically or manually, select forward or reverse rotation, choose and regulate the speed, restrict or control the torque, and prevent overloads and electrical failures. Motor controllers can employ electromechanical switching or power electronics to control a motor's direction and speed.

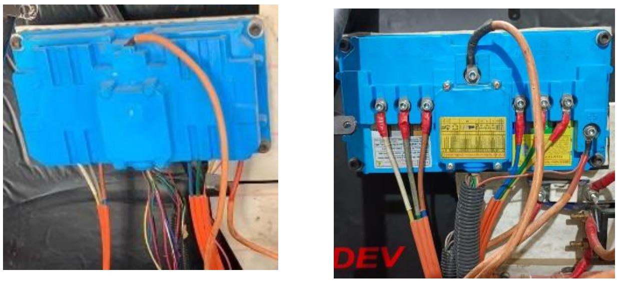
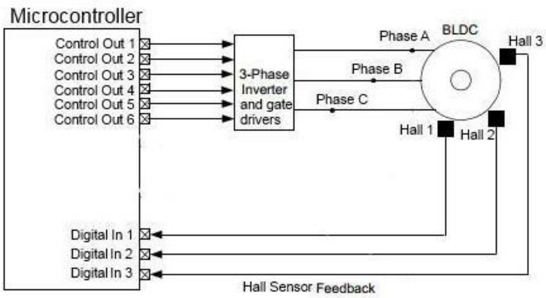


Fig.19. Motor controller (With & Without Casing)



PMSM CONTROLLER CONFIG	
Max Current	150 A
Rated Current	120 A
Voltage	48 V
Throttle Input Voltage	1.2 – 4.3 V

Fig.20. Internal circuit diagram and specifications of Motor controller

Electric Motor Controller	
Make / Model	DATAI
Available Battery Voltage (V)	48
Available Motor Power (kW)	5
Peak Phase Current (A)	25
Rated DC Current (A)	120
Maximum DC Current (A)	150
Communication Protocol	Not applicable
Throttle Input Type	Pedal feedback
Operating Temperature Range	0 °C – 50 °C
Vendor details	Eifer Megacorp Pvt Ltd

Table.6. Motor controller details

12. Main Control Unit

The main control unit provides logical control and implementation of all the starting and security sequences according to the rulebook (C.5.5). The drive mode operates whenever the brake pedal is pressed, Neutral mode applied and there is no accelerator press. The control panel is implemented using NO / NC relays and a Darlington pair type IC. The HV wire is connected to the control panel is connected using HV terminal Block.

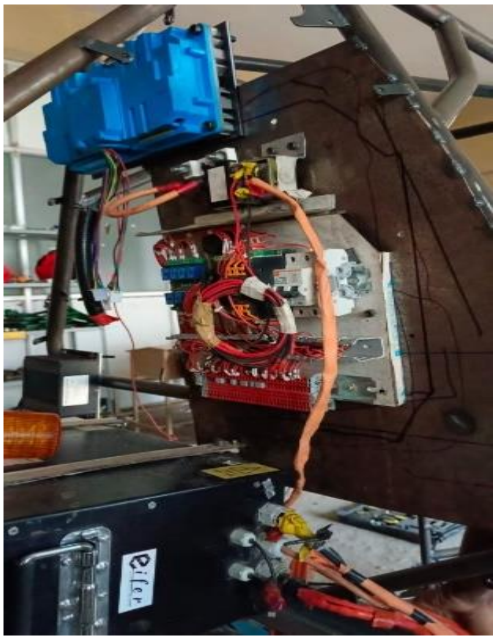


Fig. 21. Real implementation of Main control circuit with wire harness and main components

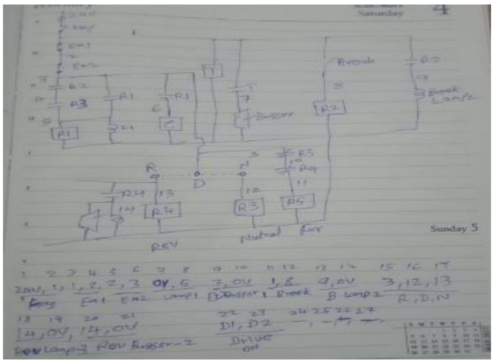


Fig.22. Circuit diagram of Main Control Unit

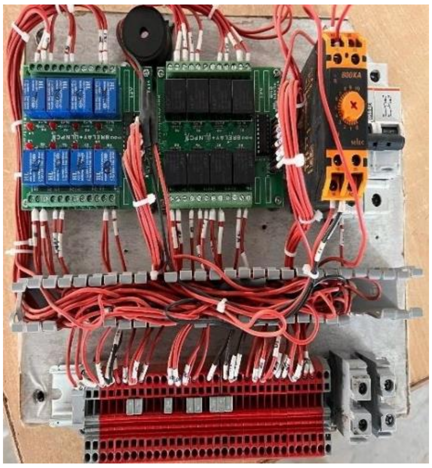


Fig.23. Control unit with spade pin terminal blocks

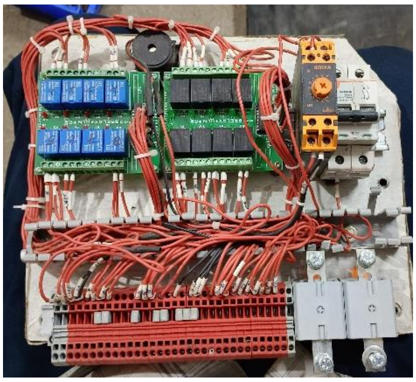
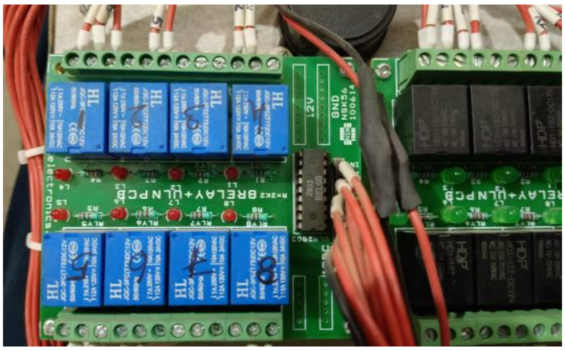


Fig.24. Control unit with bolt terminal blocks

Parts of main control unit

12.1 Relay module



This module has a significant number of relays which get different type of signals from the various part of the vehicle such as accelerator pedal push, brake pedal press, D-N-R (Drive-Neutral-Reverse) switch position, kill switch position. According to the rulebook, the vehicle must start if and only if there is brake press, no accelerator push and neutral mode. The decision of actuating the respective relay in order to achieve rule conditions is done by building the circuit accordingly. HL JQC 12-24 V Relay and ULN2903 Darlington pair ICs are used for implementing the control logic.

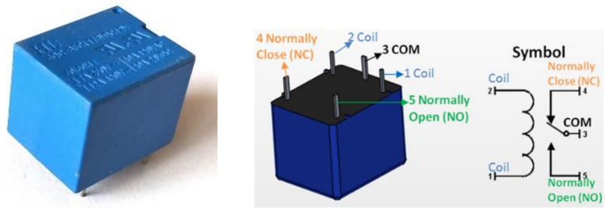


Fig.25. HL JQC 12-24 V Relay picture and relay pinout

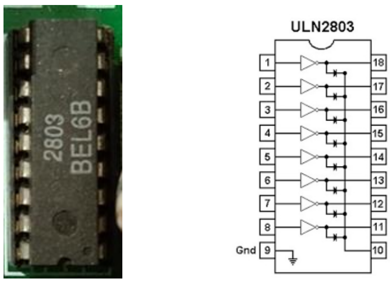


Fig.26. ULN2903 BEL6B Darlington pair ICs

Trigger Voltage (Voltage across coil)	5V DC
Trigger Current (Nominal current)	70mA
Maximum AC load current	10A @ 250/125V AC
Maximum DC load current	10A @ 30/28V DC
Package configuration	Compact 5-pin configuration with plastic moulding
Operating time	10msec
Release time	5msec
Maximum switching	300 operating/minute (mechanically)

Fig.27. Relay electrical data

12.2 Wire connectors

The signal carrying wires from various parts of the vehicle are given to the wire connector plugs which make connection with the relay logic circuit. The unwanted slots are given with filler blocks and the wires are labelled with plastic ring labels.

Fig.28. Wire connector slots

12.3 Open slot wiring cable raceway

The wires are routed with cable raceways to ensure neat and clear wire harness design and easy troubleshooting & connection purposes. This raceway also ensures non-shaky environment for wires in case of heavy vibration and shaky movement thus preventing loose connections and short circuits.

Fig.29. Wires arranged in cable raceway

12.4 Protective MCB for charging

A protective MCB is fitted as a protective device to safeguard the control unit from sudden current surges and short circuits during charging. The MCB is turned ON during onboard charging (if needed) by isolating the main circuit. L&T 10000 BB20630C is used as charging protective MCB.

Fig.30. L&T 10000 BB20630C MCB

12.5 Timer for RTDS (ready to Drive Sound)

According to rulebook 2023 C.5.7, Selec 800 XA 12 level industrial timer module is used for providing timer signal for making Ready to Drive sound (RTDS). The RTDS is made for 3 seconds whenever the driving sequence starts to indicate that the vehicle is ready for driving. A sound buzzer of 80 dB is used to deliver the sound for 4 seconds.

Fig.31. *Selec 800X timer and buzzer*

12.6 Terminal blocks

At first Connectwell CTS16U pin type terminal blocks were used. Later it is found that the wires inserted in the pin type blocks were easily loose connected because of vibration. To avoid this ring connector type bolted terminal blocks were selected. The selection of these blocks mainly depends upon input current limit, vibration factor, ease of implementation.

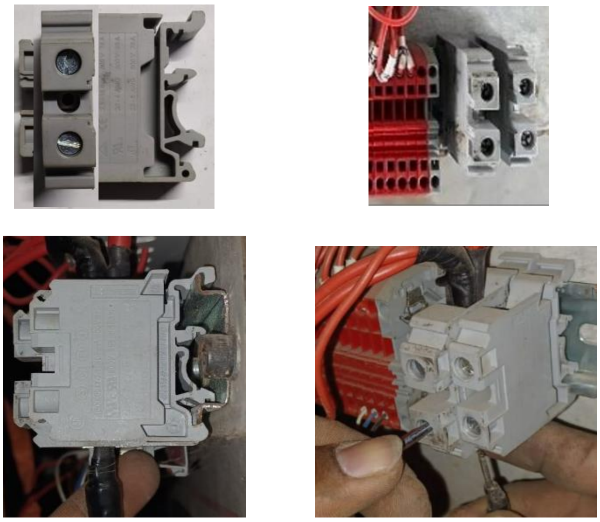


Fig.32. Old Connectwell CTS16U pin type terminal blocks

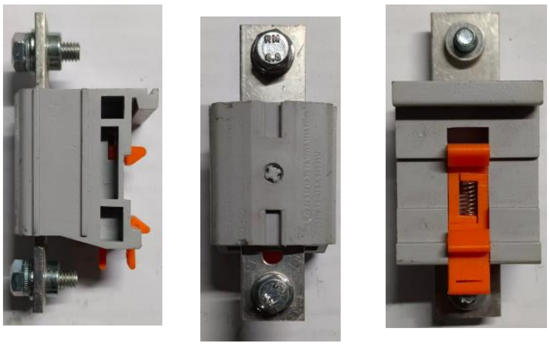


Fig.33. New bolted type terminal blocks

Fig.34. Mounting of bolted type terminal block

12.7 Electro – Thermal analysis of Electric connector plate of the terminal block

The electric metal plate of the terminal block is analysed in Ansys workbench with a given Voltage 0f 48000 mV and 100000 mA to simulate the electro-thermal properties. For that, a CAD model is designed in Solidworks.

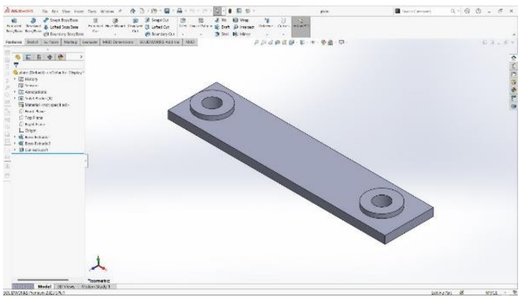


Fig.35. CAD model of electric metal part of terminal block

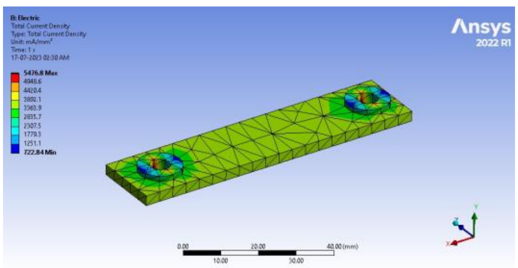


Fig.36. Total current density (mA / mm^2)

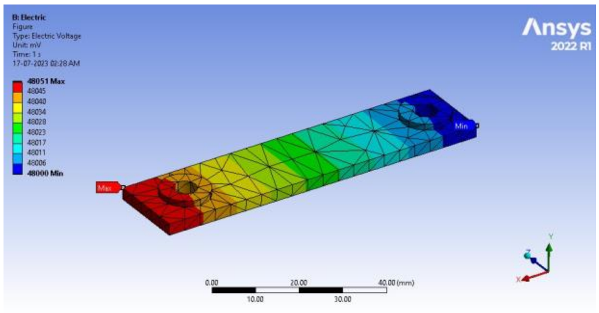


Fig.37. Transient electric voltage changes for short duration (mV / 1s)

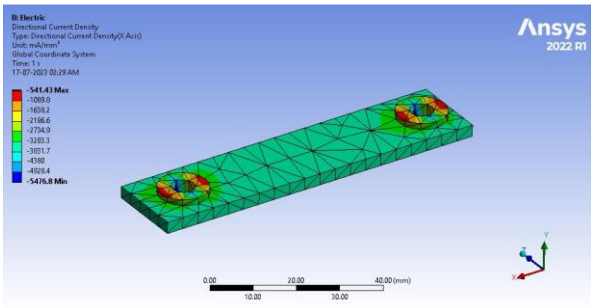


Fig.38. X axis based directional current density (mA / mm^2)

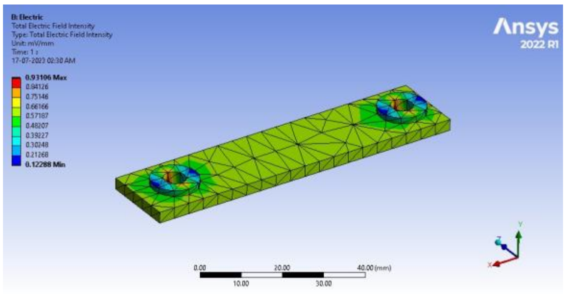


Fig.39. Total electric field intensity (mV / mm)

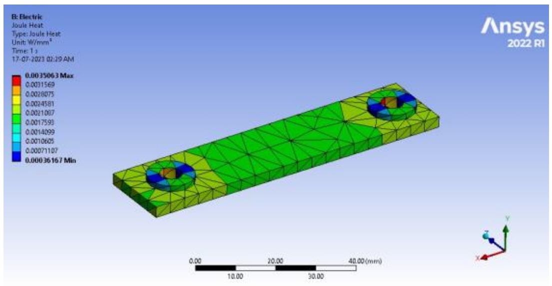


Fig.40. Joule's heating (W / mm^2)

By above simulation studies and with professional assistance, it is found that the bolted terminal block is safe and efficient and has open air circulation.

Hence the bolt type terminal blocks are used for connecting the HV wires.

12.8 Mounting plate

The whole control unit is mounted on the firewall plane by attaching a plate on the RRH (Rear Roll Hoop) plane's LDB (Lateral Diagonal Bracing) member.

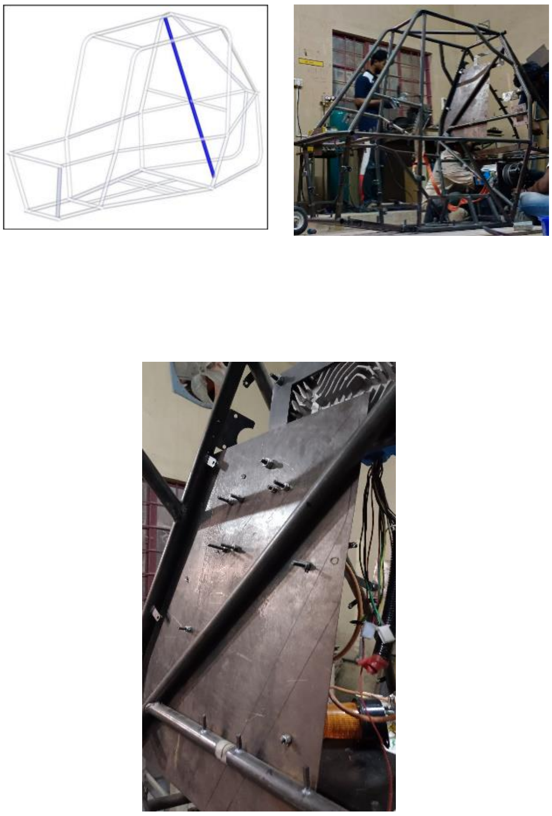


Fig.41. Mounting position and plate fixed during fabrication phase

13. Accumulator Isolation Relay (AIR)

The AIR is a protective HV equipment used to act like s switch between Battery and main circuit. It latches only when the conditions are safe. Whenever kill switch is pressed it immediately latches off and cut-off the circuit from battery. The AIR is of Normally Open Type.

Fig.42. Image of AIR

14. Driver display

A driver display is used to indicate the important parameters such as battery temperature, SoC, Voltage, Current, etc. with two bright lamps (Red and Blue) are used to indicate the live status of the High Voltage (HV) Tractive system and Grounded Low (GLV) Voltage system as per rule C.5.8. The mounting of the display panel is designed and 3D printed and fastened in the cross member of Both front bracing members of the roll cage.

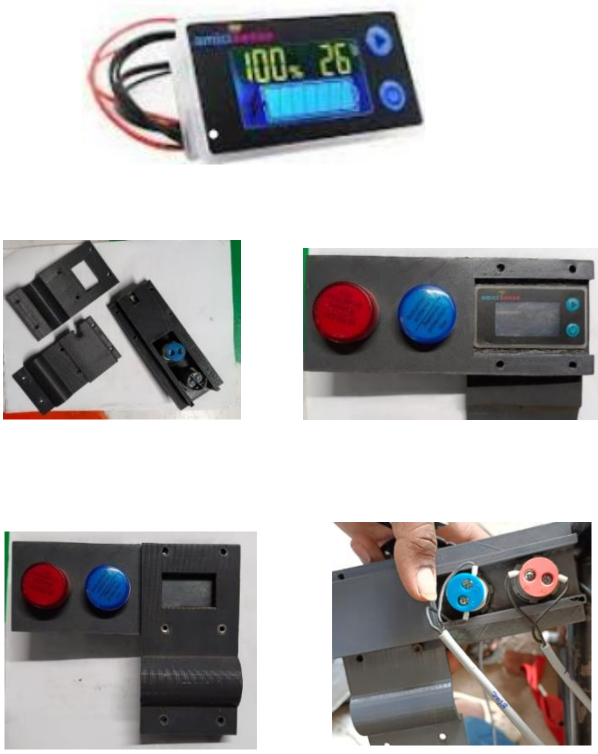


Fig.43. Driver display with red and blue panel lights fitted inside a 3D printed holder case

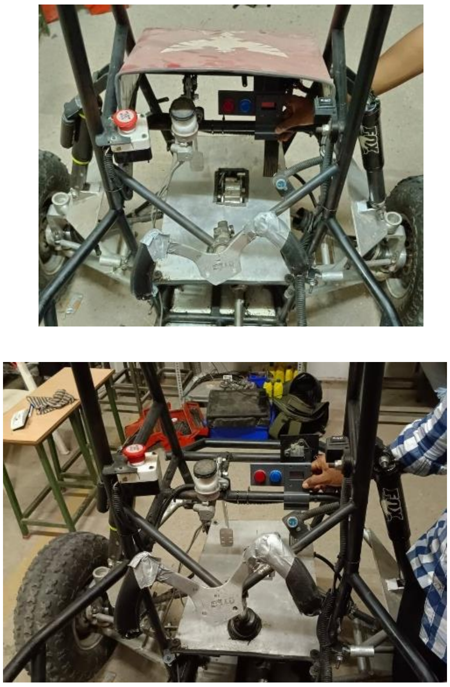


Fig.44. Mounting of driver display in the vehicle

15. Fuse

The fuse for protecting the Accumulator(s) tractive system circuit must have a rating lower than the maximum peak current of the isolation relays. Each of the electrical systems (both GLV and Tractive system) is protected by providing a fuse of the rating greater than the current rating of the electrical system. The current rating of a fuse is not be greater than the peak current cut-off rating. The fuse is of automotive grade and it is instant blow type with 500 ms time delay.

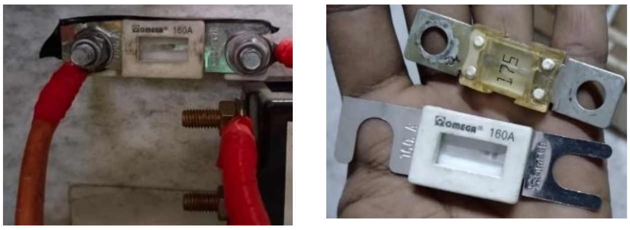


Fig.45. Images of HV protection Fuses

Since the fuses withstand very high current cycles constantly during the running condition and produce enormous heat, a fuse holder made up of good insulative material is mount on which the fuse is fixed. TosunLux FBA01 fuse holder is imported from Minnesota, US and used as fuse holder.

Fig.46. TosunLux FBA01 CE certified IEC grade fuse holder

16. HV cut-off switch

An HV-rated cut-off switch is connected between the tractive system Accumulator(s) and the DC-DC Converter. The DC-DC Converter is de-energized (no voltage detected at the input terminals) when the HV-rated cut-off switch is off. When the HV-rated cut-off switch and GLV ignition/master switch is on, it continues to power the safety appliances and auxiliaries irrespective of the kill switch position. Milltec c10 240V model is used as HV cutoff switch.

Fig.47. Image of HV cut-off switch

17. Grounded Low Voltage Systems (GLV)

The GLV system consist of lights, alarms and other ancillaries. The Tractive System Activated light (TSAL) indicates the operation of High Voltage Traction system. The reverse light and reverse alarm indicate the working of reverse operation. The brake light operates whenever brake is applied. The driver indication lamps indicate the GLV and HV status to the driver. The ignition key is used to start the vehicle. The FNR switch is used to toggle between Forward Drive / Reverse mode / Neutral condition. The kill switches are used to open the complete circuit of the vehicle whenever an emergency situation occurs. The Ready to Drive sound operates whenever the vehicle is started, for 3 seconds.

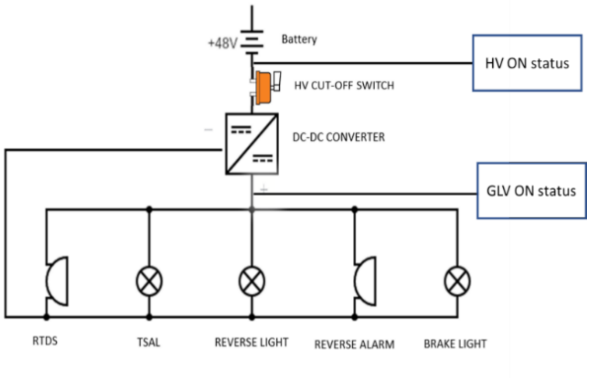


Fig.48. GLV circuit diagram of the vehicle circuitry

17.1 Brake light

The brake light is purchased as OEM satisfying the rulebook constraints. AIS standard homologation mark engraved brake light is purchased from authorized dealer. The light is energized whenever the brake is pushed. The brake light energizing circuit simply has two automotive pressure switches, brake light, relay, power source (DC-DC converter here). The light is in adherence to BAJA SAE J586 and J759 standards. Hydraulic pressure switches are mounted on the ancillary output ports of master cylinder. They get activated using the brake fluid pressure during braking conditions and act as a switch closing the brake light circuit.

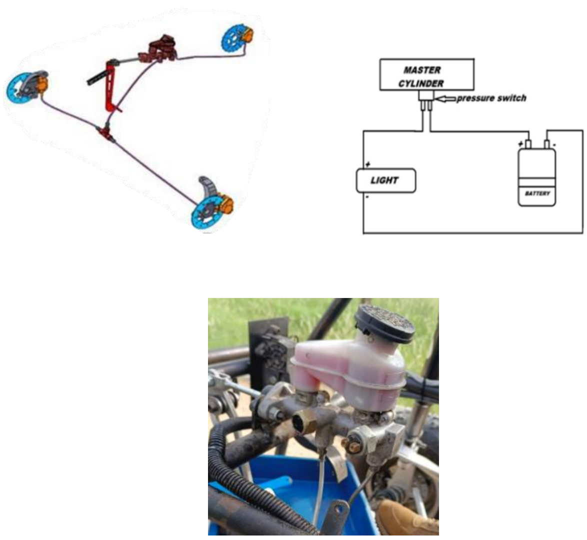


Fig.49. Brake circuit, Brake light circuit and pressure switch

Brake light

Pressure switch

Fig.50. Arrangement of pressure switches on the master cylinder

17.2 Reverse light and reverse alarm

The reverse light and reverse alarm are bought as OEM with AIS standard as specified in rulebook. The reverse light and reverse alarm are energized whenever the D-N-R switch is put on R – Reverse mode. The light has “R” engravement and satisfy SAE J759 standard. The reverse alarm has J17941 standard. The reverse alarm and reverse light are positioned as per rulebook (27.6 inches above ground).

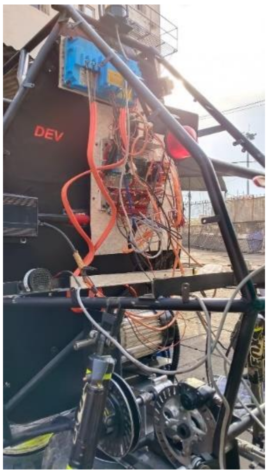


Fig.51. Reverse light and reverse alarm, Their mounted positions on the vehicle

17.3 Kill switch

The kill switches are used to completely cut-off the powertrain circuit from the power source in case of emergency situations and causalities. They de-energize all the components except the brake lights. The kill switch is of E-stop, PUSH TO KILL and PULL TO ROTATE type. Two kill switches are mounted on the vehicle. One is at Driver cockpit side along the SIM (Side Impact Member) and another one is at lateral side of the vehicle. The rear kill switch is positioned on the right side of the vehicle, aft of the plane of the RRH, and forward of the right FABUP for easy access for track workers or volunteers.

Fig.52. Kill switch – Original image and Opened view of two connected Kill switches

The mounting brackets for both the kill switches are designed in AutoCAD software and manufactured using Laser cutting. The manufactured brackets are fixed using TIG welding. Utmost consideration is given for Kill switch mounting is given since it is more prone to Roll over and collision.

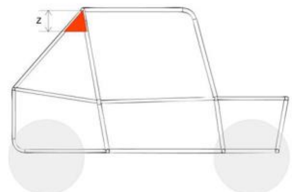


Fig.53. Mounting bracket of Kill switch and Rear Kill switch mounting position as given in Rulebook

Fig.54. Mounting of Kill switches on the vehicle

17.4 TSAL light

TSAL (tractive system activated light is used to indicate the Tractive system ON status. The TSAL is IP65 rated and has >350 Lumens of brightness. It is mounted inside a cage fitted on the centre of BLC (Overhead Lateral Cross member).

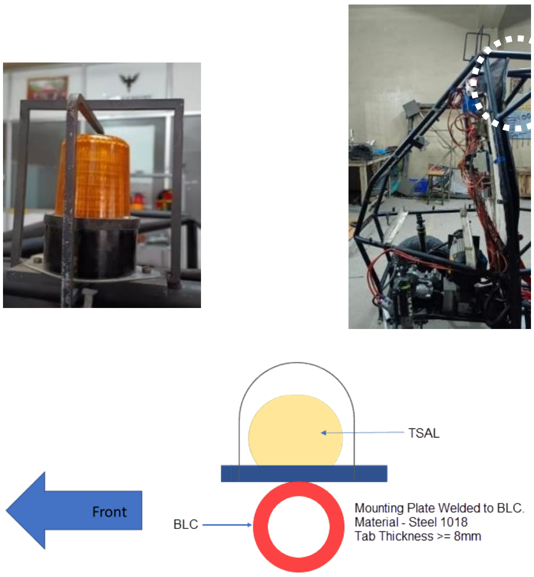


Fig.55. TSAL fitted inside a cage and the infographic given in rulebook

17.5 Ignition key

The ignition key completes the circuit flow when turned. The AIR and tractive system de-energize when it is turned OFF.

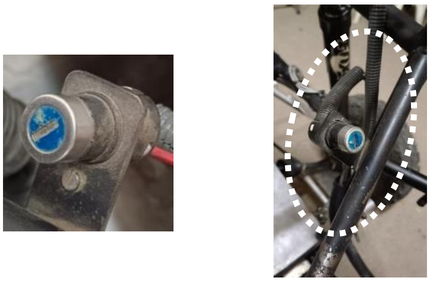


Fig.56. Ignition key and position of ignition key on the vehicle

17.6 F-N-R switch

The F-N-R (Forward -Neutral-Reverse) switch is used to switch over from forward driving, Neutral condition and reverse mode. The signal from this switch is given to both the motor controller as well as to the Main Control unit for Motor operation and vehicle operating sequence as per rulebook.

Fig.57. Ignition key and position of ignition key on the vehicle

GLV Components configuration	
1. TSAL Specifications	
Make / Model	Cali – International
Colour	Amber
Flash rate	5
Operating Voltage (V)	12 V
IP Rating	65
2. Ready to Drive Sound	
Make / Model	INEBIZ
Control Voltage (V)	14
Sound intensity (dB) at 2m	81
3. Fuse	
Current Rating (A)	160 A / 150 A
Voltage Rating (V)	54.6 V / 48 V
Type (Instant blow/Delay blow)	Instant blow
4. AIR	
Make / Model	Main Contact HV Contactor
Contact Current (A)	200 A
Contact Voltage (V)	48 V DC
Type (Normally Closed/Normally Open)	Open
5. Firewall	
Insulating layer thickness (mm)	0.8 mm
Insulating Material Make / Model	UL94O
6. Kill Switches	
Type	Push to kill
Number of Kill Switches	2
Working Voltage (V)	12
7. Ignition Switch	
Type (Switch, Key etc.,)	Key
Working Voltage (V)	12
8. Lights	
Name of Light	Brake light
Make/OEM	MINDA
Colour	Red
Name of Light	Reverse light
Make/OEM	REECE
Colour	White

Table.7. GLV system specifications

18. Wirings and Insulation

The HV wirings are insulation sleeve insulated. The HV wiring is connected using ring connector to ensure safe and better connection. The firewall and the inner walls of the control panels are insulated using the UL94-V0/FAR25 Nomex material (“H” Class) which is rated “H” class and can withstand high temperatures and High voltages. For testing its reliability, small flame is induced and the material heat spread stopping property is checked. The connection joints are insulated. The HV components are marked with High Voltage warning sticker. The wires are insulated with insulative orange sleeves to protect from thermal runaway. The + and – terminals are given proper colour codes for polarity identification.

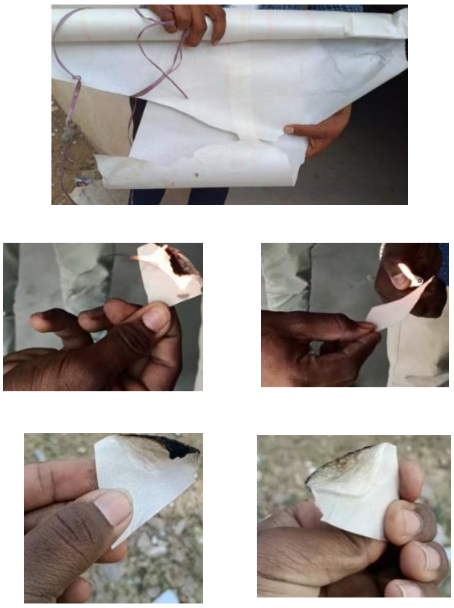


Fig.58. H class Nomex material and flame testing

Fig.59. HV warning stickering on motor, UL 94 Nomex sheeting on Control panel casing and side protection panels

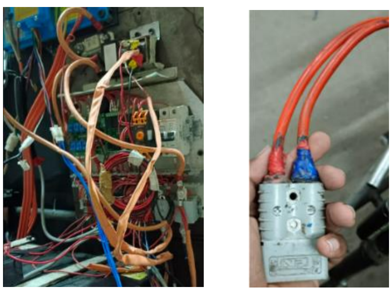


Fig.60. Orange insulative sleeve protection and colour coding of terminals

Fig.61. High voltage warning in motor, DC-DC converter, Battery pack

The connectors used in previous years caused loose connection and caused unreliable effects like heating. So, ring connectors (RC), insulated twin end lugs were used. The wires with lugs and connectors were crimped with crimping tool for better grip.

Fig.62. RC for HV and GLV systems, Lugs, RC open cable ring lug

The wire conduits or hoses were used to protect the wires from external damage and to neat wire routing. The wiring at cockpit and wiring at Motor vicinity is given more priority since it involves more safety from crash and rotating components. The zip ties were mostly used to tie up the wire routes with the chassis to protect from vibration and vehicle movement. Duct tapes and insulation tapes are used for protecting the terminals and wires from electrical damages, short circuits.

Fig.63. Member tied non exposing small conduit wire routing

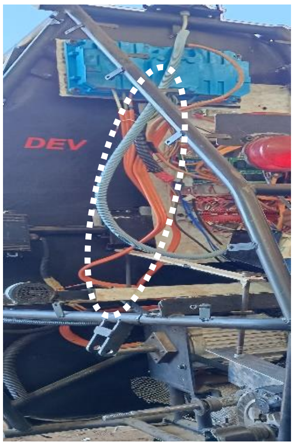


Fig.64. Motor controller, Motor HV wiring route inside a conduit

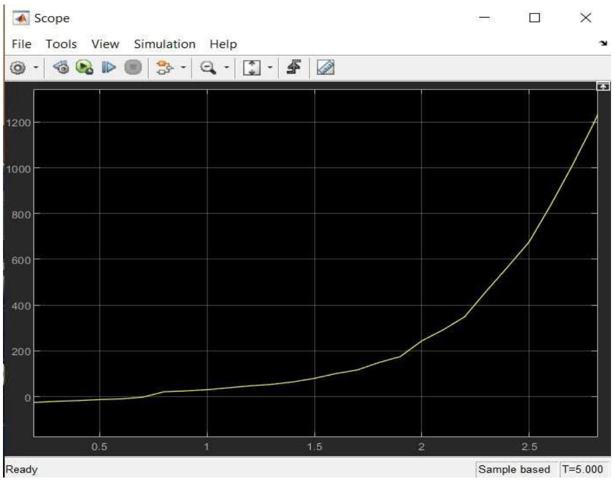


Fig.67. MATLAB Simulink simulation of CVT setup for finding relation between CVT Springs and engagement RPM

19. CVT Tuning Using MATLAB Simulink

The Tuning of GAGED GX9 CVT is simulated in MATLAB-Simulink and the purpose is to engage the buggy @500 RPM by changing the flyweights and spring stiffness in the primary pulley and tuning of the shift speed in the secondary pulley is in process

The graph ultimately illustrates the engagement of the buggy when the centrifugal force exceeds the opposing force exerted by the spring.

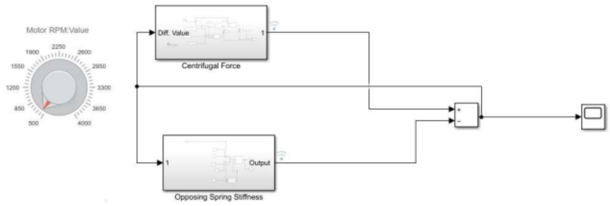


Fig.65. MATLAB model of Primary Pulley Setup with Motor RPM

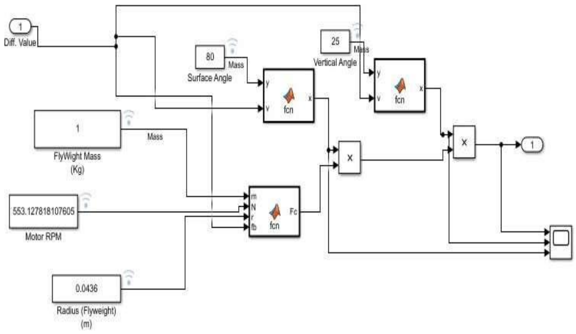


Fig.66. MATLAB model of centrifugal Weights and Spring Stiffness

20. Starting sequence

The starting sequence of the vehicle is followed according to the rulebook. The HV system energizes only when there is no accelerator pedal push, must brake push and Neutral mode.

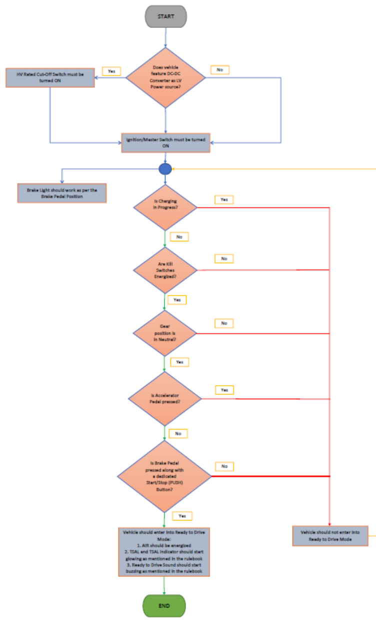


Fig.68. Drive sequence flowchart given by BAJA SAE India

The limit switch placed behind accelerator pedal is used to detect whether there is a throttle push or not. Neutral position is identified by using signal from F-N-R switch. The brake press is identified by pressure switch circuit connected to master cylinder and main control unit.

Fig.69. Limit switch and placing of limit switch behind the accelerator pedal

21. Electrical control panel protecting case

The electrical control panel case is designed in SolidWorks and CAE analysis is done in Ansys. Aluminium is selected as material of construction. Inner temperature of 35° is fixed and ambient temperature analysis was done. The case protects the main control circuit from water or mud splashes, external disturbances, dust, etc.

Heat flux (In W/m²)	Min: 65.397
	Average: 102.13
	Max: 108.96

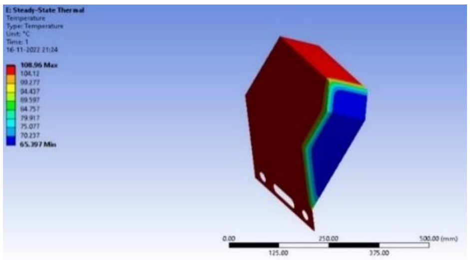


Fig.70. CAE analysis of Electrical control unit casing

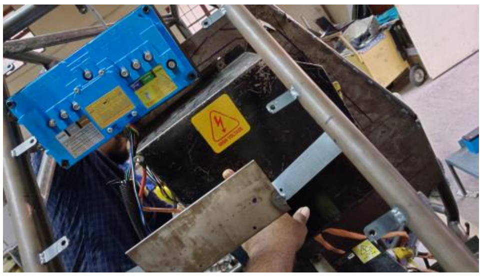


Fig.71. Implementation of Main control circuit protection case

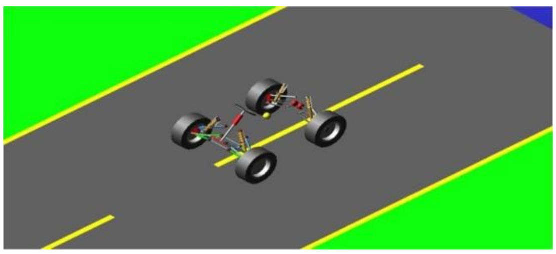
22. Acceleration Test analysis using MATLAB Simulink

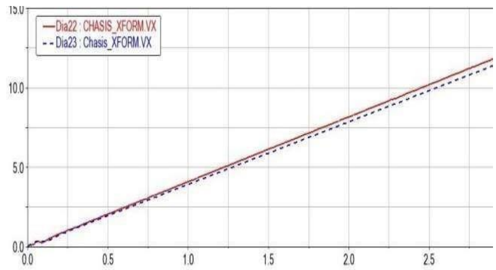
The main objective is to find the acceleration of the vehicle with two different tyres of dimension 22x7 inch and 23x7 inch. The acceleration test was carried out for a 30 – meter straight road with different tyre of dimensions 22x7 inch and 23x7 inch.

The result was found to be that 22x7 inch tyre had better acceleration than 23x7 tyre.

Boundary conditions were set as,

- MATLAB Road length = 30m
- Torque = 560Nm





MATLAB Simulink analysis with GUI of Vehicle speed with relation to Wheel size and road length to find maximum acceleration

23. Design of drivetrain casing

From the studies, CVT is prone to slippage at higher temperatures. To minimize the operating temperature, forced convection through well-placed air vents in the CVT casing is the best possible solution. To understand the flow of air at operating temperature, CFD iterations were performed with various designs of CVT casing. Ansys is used to find the heat transfer and maximum temperature of the CVT within the given boundary condition.

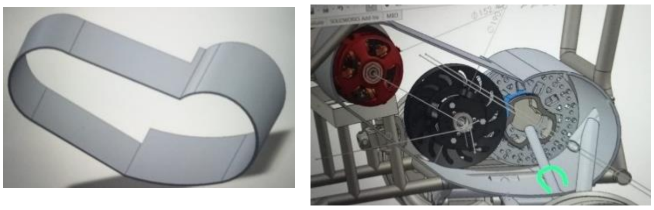


Fig.72. CAD of CVT casing

Fig.73. CVT casing with wire mesh – implementation

Design of Motor mount plate

The motor mount plate is designed such that the motor is placed with no hindrance and correct alignment in the powertrain transmission. The measurements with accurate tolerance play a great role in successful manufacturing of this part.

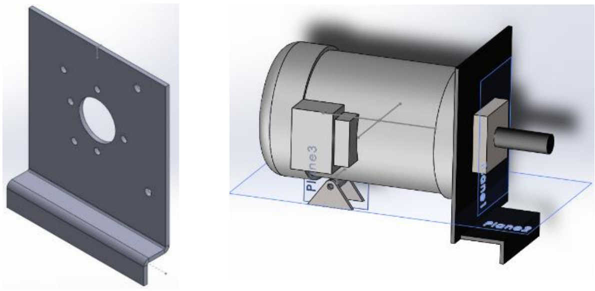


Fig.74. CAD of Motor mount plate

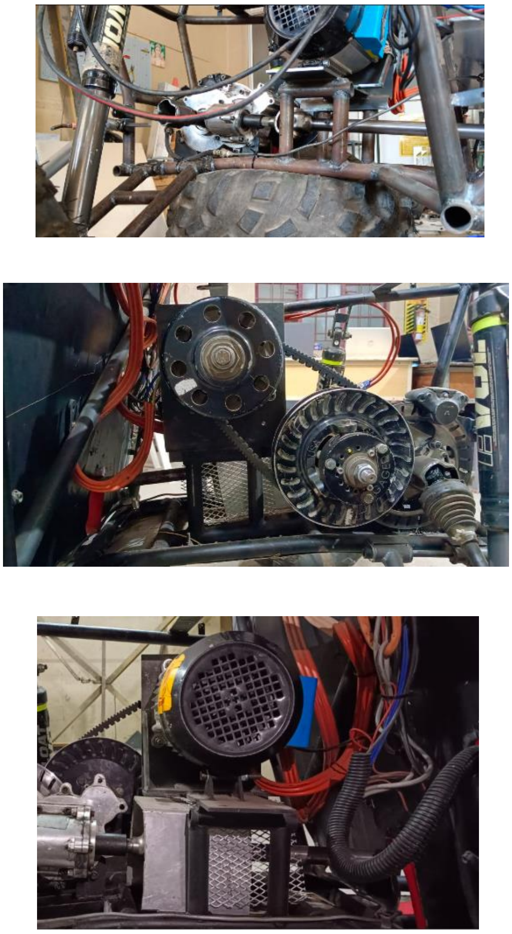


Fig.75. Assembly of motor mount

24. Positioning of Motor controller

The motor controller is positioned such that the heat is easily dissipated from the heat sink.

Fig.76. Motor Controller fixing – heat sink with ventilation

25. Mounting brackets of Motor controller and DC-DC converter

The motor controller and DC-DC converter were mounted using a platelike Nomex insulated bracket in the backside of RRH plane.

Fig.77. Mounting bracket

26. Test run incidents

26.1 Wire loosening and melting – abrupt heat formation

During the test runs, the electricals side made small problems like wiring point loosening by vibration, wire excess heating, Uncontrolled load, etc. All problems have been immediately addressed with author's work and also with skilled persons assistance and solutions were implemented by keeping safety as first priority.

Wire excess heating cause identified as vibration. Because of vibration, the improper fastened lugs got slight movement and over the course of time it creates enormous meat at fastened point which spreads to nearby wiring insulation causing them to melt.

Fig.78. Wiring junction point melted because of vibration induces fastener loosening

26.2 Uncontrolled power management

The driving cycle is unpredictable and the torque – speed requirements vary for the ATV. Because of high load requirement, the wire harness easily damaged. To avoid this the load current, maximum instantaneous discharge current was inferred using the smartBMS app. Since the app can provide the data only in Bluetooth short communication range, the mobile phone is given to the driver and the results were screen recorded. Accordingly, the fuse and wiring thickness with ventilation is arranged in next test run.

Fig.79. Varied current discharge ranging from >140 A and < 20 A

26.3 Breakage of Pressure switches

The pressure switches can't able to handle enormous brake pressure and they easily deformed during test runs. So, the dimensions and OEM brand is changed and the better switch is implemented.

Fig.80. Deformed pressure switch

26.4 Fuse failure

During test runs, the fuse of 160 A got blown up and later it is found that the continuous excess current demand caused the fuse to blow. Then, the driving cycle pattern is adjusted and the driver is told to follow the same. This led to smooth performance with normal heating of the fuse.

Fig.81. Blown fuse after heavy load application

27. Design Validation plan chart

Design Validation plan for the whole project is created to identify the project flow obstacles with accordance to the main objectives.

Sl. No.	Level: Vehicle, Aggregate or part	Performance Target	Acceptance Criteria / Target	Validation Test & Method	Test Resource/ Equipments used
1	Weld test (Part)	The weld should withstand the load conditions.	No welding defects must exist.	(Liquid penetrant test) Weld shall be cleaned. The penetrant and developer is applied to the test surface and checked for Surface Defects.	Cleaner, Penetrant, Developer
2	Crash test (Vehicle)	The Vehicle should not disintegrate.	The vehicle should resist Physical Deformation.	By using Hypermesh software, the crash test is simulated.	Hypermesh software
3	Egression test (Aggregate)	The driver must eject out of the buggy within 4 seconds	Time taken to eject out must not exceed 5 seconds	The driver is buckled up with all safety equipments and the ejecting time of driver is noted	Stopwatch
4	Tire wear test (Part)	The buggy must run without any change in static camber angle	The tire must wear as per the given camber angle without any offset wear	Buggy is set up as per designed camber and tire wear is noted after each test.	Vernier Calliper, Bevel Protractor
5	Brake test (Aggregate)	Stopping distance should be within 6 meters	All the wheels must be locked during braking and the vehicle must stop within 8 m.	The buggy is accelerated to 40 kmph in a straight track and the brakes are applied. Different road conditions are considered and brake test is done.	Test track
6	Straight line stability test (Vehicle)	The vehicle must maintain its steering wheel angle at 0^0	Steering wheel angle during dynamic condition must be within $\pm 2^0$	The buggy is accelerated to certain speed and the hands are taken off the steering wheel.	Test Track
7	Turn circle radius (Aggregate)	Turn circle radius must be 1.7 metre	It must turn within the specified radius.	The buggy is made to steer into figure of O its radius measured.	Measuring tape
8	Hill climb test (Aggregate)	Gradeability should be 50%	The buggy must be able to a climb a 25^0 slope	The buggy is made to climb a 25^0 slope for a distance of 30 meters	Ramp inclined to 25^0 from the ground
9	Acceleration test (Aggregate)	The Buggy must accelerate up to 1.20 m/s^2	The buggy must cover 30 meters in 10 seconds (1.20m/s^2)	Buggy is accelerated on a 30 meter straight track and the time taken is noted.	Test track, stopwatch
10	Top speed test (Aggregate)	The buggy must be able to achieve a top speed of 56 kmph	Top speed should be at least 50 kmph.	Buggy is made to run at its maximum Engine rpm and the vehicle speed is measured.	Speed sensor
11	Gear profile test (Part)	The gear profile must be involute.	The gears must mesh with each other	The gear is measured by shadowgraph technique	Profile projector
12	Gear life cycle test (Part)	Life span of the gears must be 200 Hours	The gears must withstand the wear for the given life cycle	The gearbox is connected to a motor and made to run periodically for 10 hours under load conditions. Gear Wear is checked at regular intervals.	Test rig
13	Drop test (Vehicle)	The Vehicle must withstand its structural integrity when dropped from a height of 5 Feet.	No breakage of components must occur	The buggy is dropped from a 5 feet height.The drop is videographed and checked for body motions.	camera

Table.8. Design Validation plan chart

28. DFMEA & PFMEA analysis of the project

The Design / Process Failure mode Effect analysis creates an in-depth view of solving problems which arises throughout the development of the project. The problems were identified based on their severity, frequency and easy detection levels and the solving approach was formulated based on the priority level.

Item / Function	Potential Failure Mode	Potential Effect(s) of Failures	Sev	Potential Cause(s)/Mechanism (S) Of Failures	Occ	Current Design Control	Det	Rpn	Recommended Action(s)
Roll cage fixtures	Leads to intense assembly errors and geometrical inaccuracies	Assembly Problems	5	Poor welding fixtures that does not arrest the intended DOF	8	Wooden fixtures	4	160	Frequent monitoring of accumulator parameters
Throttle Pedal	Disengagement from fore aft bracing (low),signal sent by throttle pedal to motor is hindered	Reduce performance in some cases not operable at all	8	Improper welding, excessive pedal effort from drive wiring between pedal and motor controller is halted.	6	Safety casing and Frequent checking , cleaning	8	384	Weld efficiently : check the wiring thoroughly with proper insulation
BMS	Failure of BMS due to thermal run away and over power	Uncontrolled accumulator parameters which affect other equipments and may cause hazards	5	Seldom monitoring of battery parameters Improper tolerances	8	Battery checking through app	4	160	Accurate dimensioning
Machine (hubs and uprights)	Improper dimensions	May result in manufacturing malfunctions	6	Improper tolerances	4	Manual filing	2	48	Use of alternate fixtures with high accuracy
Design of mounting brackets	Unparallel brackets leading to assembly problems	Brackets tend to bend on shock loads	7	Improper welding/positioning , bracket thickness	6	Manual marking of mounting points on roll cage	3	126	Improvised design with proper thickness (3mm)
Welding of Suspension mounting brackets	Rupture of brackets onto rollcage, bracket displacement	Unbalanced Geometry, may result in poor steering and damping	6	Angular variation (brackets)	8	Rework	6	288	Ensure the brackets are parallel to each other
Steering Arm	Rupture or bending of steering arm bolt	Can cause considerable damage to the steering arm	7	Usage of 8.8 grade bolts	6	Frequent change of bolts	4	168	Usage of bolts with high strength
Gear box casing	Gear teeth failure	Results in uneven meshing	8	Improper heat treatment	3	Frequent oil refill	2	48	Proper assembling of gearbox
Tie rod ends	Limits the steer angle and the motion of tie rod	May result in poor steering or failure of rod ends	8	Fail to attain required articulation	4	Frequent change of rod ends	2	64	Increased articulation of rod ends
Tripod joint drive shaft	Plunge out	No power transmission	8	Higher transmission angle	7	Prevention	2	64	Choosing appropriate shaft length

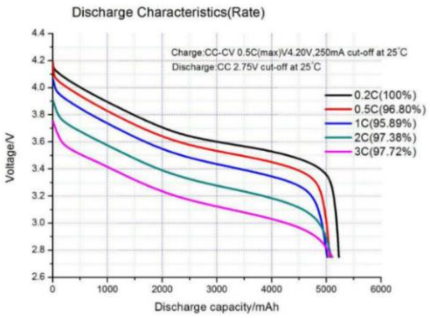
Table.9. Design / Process Failure mode Effect analysis

29. Safety standards

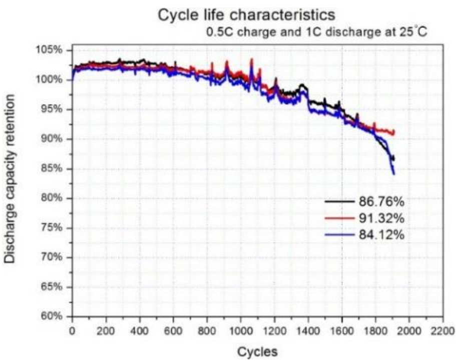
All the components, systems, sub-systems, assemblies, designs are made according to industrial standards such as AIS, IEC, IEEE, AISI. To make sure that there is high grade output with increased safety. At all places such as work area, charging station, swapping area standards are followed for correct and efficient results.

Fig.82. Charging station of battery pack

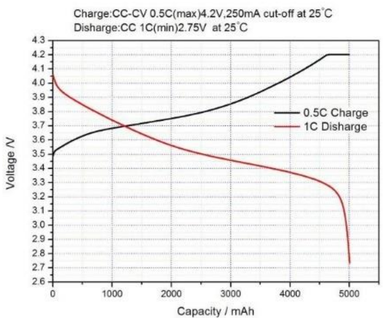
30. Graphs



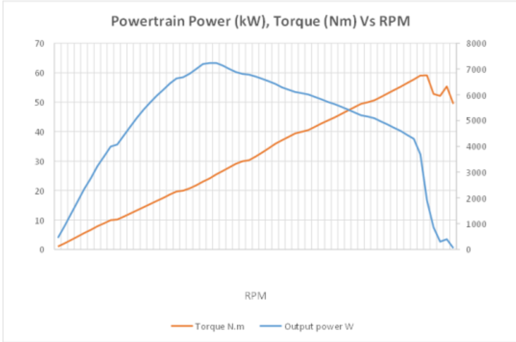
Graph. No. 1 Charge and Discharge characteristics curve



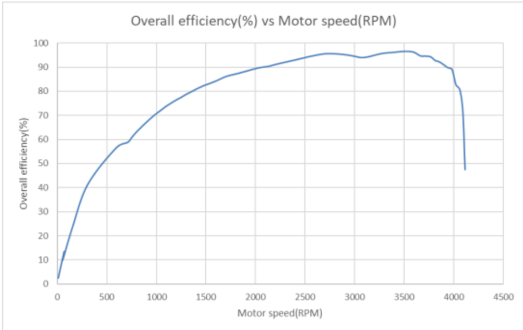
Graph. No. 2 Cycle life characteristics curve



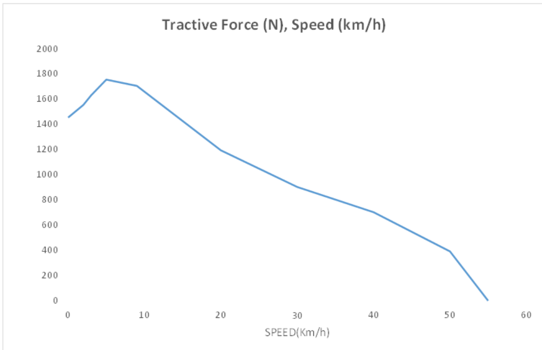
Graph. No. 3 Rate discharge characteristics curve



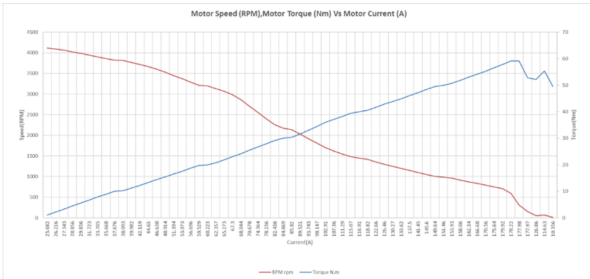
Graph. No. 4 Powertrain Power (kW), Torque (Nm) Vs RPM



Graph. No. 5 Overall efficiency (%) vs Motor speed (RPM)



Graph. No. 6 Tractive Force (N), Speed (km/h)



Graph. No. 7 Motor Speed (RPM), Motor Torque (Nm) Vs Motor Current (A)

31. Additional mounting components of the system

Motor is mounted to the chassis via a plate. For connecting the metal plate, an external designed mount is used. The motor shaft is coupled to this motor mount and the primary pulley of CVT is connected on another end thus making a linear shaft arrangement.

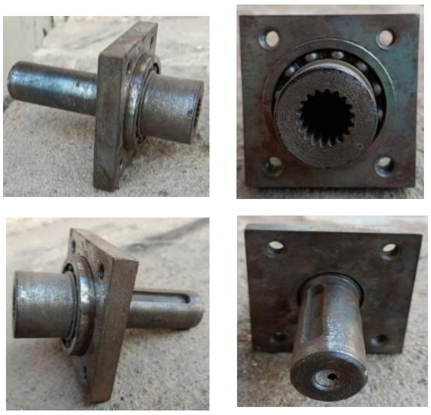


Fig.83. Motor mount

The battery is mounted to the chassis using “L” bracket mounts. Battery stopper brackets are manufactured in-house.

Fig.84. Battery stopper mounting brackets

The battery holding “L” brackets were inhouse designed and manufactured.

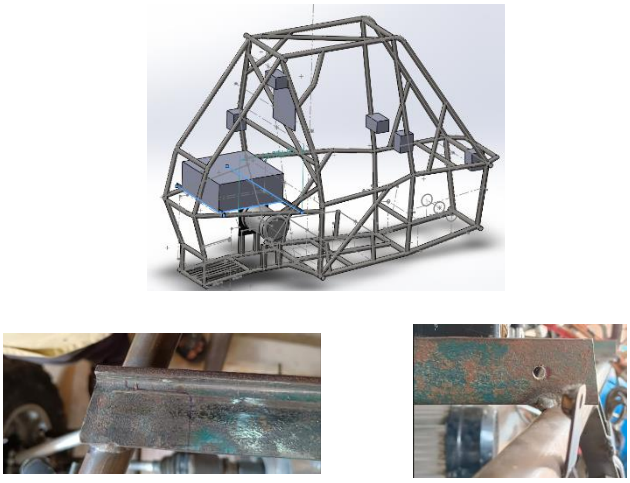


Fig.85. mountings of Parts and battery holders

The driver is safeguarded from the propeller shaft by implementing a propeller shaft casing made up of thick Aluminium sheet which is blended into a hollow tunnel shape for protection.

Fig.86. Battery stopper mounting brackets

A swapping cart is designed and fabricated to take the accumulator from one place to another. The dimensions and wheel size, insulation property was given according to the rulebook C.9.2.2.

Fig.87. Hand cart fabrication and Insulation coating using Nomex “H” class material

32. Design Comparison of previous year design and current new design

The comparison of previous year design with new year design makes the team to optimize the sub system design flow. The sub wings of the team identified the pros and cons and designed accordingly.

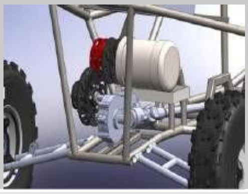
Previous year’s design	New design
	
Last year we opted for 2 Wheel Drive (2WD)	In new design we adopted to 4 Wheel Drive (4WD)
Traction was reasonable	More traction is achieved due to the 4WD setup, which helps to drive the vehicle on slippery surfaces, with comparatively minimal tractive effort
Pin type connector blocks used.	Ring connector type pins and blocks used.

Table.10. Design Comparison

33. Standards followed for the fabrication process of the vehicle

Some of the SAE, AIS standards are followed throughout the fabrication process of the vehicle under the regulations of Rulebook. Some of them are:

- SAE standard J759
- SAE standard J1741 or J994
- IEC 60529 IP67 standard
- IEC 61851 - 1
- UL94-V0/FAR25 Standard
- 1000V VDE, IEC 60900 standard
- ASTM D120 or EN 60903 standard
- AIS 048/156

Abbreviations

HV - High Voltage

GLV - Grounded Low Voltage

DC - Direct Current

AC - Alternating Current

MCB - Miniature Circuit Breaker

SAE – Society of Automotive Engineers

2WD – Two-wheel drive

4WD – Four-wheel drive

TTE - Total Tractive Effort

ATV – All-Terrain Vehicle

WKT - We Know That

kW - kilo Watt

Ah - Ampere Hour

SoC – State of Charge

D0D – Depth of Discharge

SoH – State of Health

IEC - International Electrotechnical Commission

AIS - Automotive Indian Standards

IP - Ingress Protection

OD - Outer Diameter

ID - Inner Diameter

BMS - Battery Management System

PMSM BLDC - Permanent Magnet Synchronous Brushless DC

RPM - Revolution Per Minute

LED - Light Emitting Diode

IC - Integrated Circuit

NO - Normally Open

NC - Normally Connected

COM - Common

RTDS - Ready To Drive Sound

dB - decibel

LDB - Lateral Diagonal Bracing

SIM - Side Impact Member

RRH - Rear Roll Hoop

BLC - Overhead Lateral Cross member

AIR - Accumulator Isolation Relay

TSAL - Tractive System Activated light

TIG - Tungsten Inert Gas welding

RC - Ring Connector

CAD – Computer Aided Design

CAE – Computer Aided Engineering

CVT – Continuous Variable Transmission

OEM – Original Equipment Manufacturer

FOS – Factor of Safety

DVP – Design Validation Plan

DFMEA – Design Failure Mode Effect Analysis

PFMEA – Process Failure Mode Effect Analysis

Conclusion

For an off-road vehicle to operate safely and effectively, like an ATV, its E - Powertrain is essential. To make sure the car can travel across rough terrain, the E-Powertrain system must be designed and optimized. We have discussed the SAE E-BAJA (ATV) vehicle's E-Powertrain design, analysis, and implementation in this work. Based on the specification, we created and bought the components. Safety aligned with standards are given as first priority. The Electrical powertrain system is designed and implemented in such a way that it can withstand any type of problems.

The materials' FEA and CAE analyses provided an opportunity for optimization. The powertrain team had numerous difficulties, including component failure, an absence of electrical components, difficulties with the drawing of the control system, and assembly incompatibility of the entire system. However, it took over them all and put the system into place successfully. Through this work, the powertrain team demonstrated their capability and helped in optimization of the vehicle. There is a plenty of room available for improvements and innovation. In upcoming years, the team can achieve this by learning from the past works. Through this paper, we believe that we have showcased our work and findings. It can serve as a guide for future designers and engineers working on similar projects.

Acknowledgement

We want to sincerely thank Dr. A. Vadivel, our faculty advisor, for his guidance and assistance with this project. His encouraging words and insightful advice have been crucial to this project's success.

We also want to express our gratitude to the entire crew for their unwavering commitment and hard work in developing and perfecting the suspension and steering system for the SAE E-BAJA (ATV) vehicle. The targeted performance and safety requirements have been attained thanks in large part to their dedication and hard work. Finally, we would like to express our gratitude to the SAE organization for giving us the chance to display our engineering expertise and innovation by competing in the SAE E- BAJA competition. We are thankful to the entire team members' family and friends for their motivation and support through hard times. Thank you all for your contributions and support

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