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Electrical Design of Off-Road Electric Vehicle

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***Abstract*—The study, design, and construction of every electrical system required to create a fully functional off-road EV are presented in this report. Three main electrical categories were required, namely critical vehicle systems, e.g. engine control unit integration with engine sensors and a motor-controlled shifting system, safety systems and the additional designs that added value to the vehicle, e.g. an electronic driver interface, digitally controlled shifting etc.**

***Index Terms*— Accumulator, BLDC motor, Simulink, Efficiency.**

I. Introduction

The benefits of EVs include increased energy efficiency due to regenerative braking and newer packaging options, along with a reduction in CO2 emissions. The goal of this thesis is to increase understanding of the benefits of electric power trains and how they might be used[1]-[2]. The objective of the paper is to highlight that how different choices affect the vehicle dynamics, how the motors and gears might be configured and the way the accumulator pack and motor controller might be designed to maximize the performance of the car.
Many experts are looking for alternate energy sources because of the problem of air pollution caused by automobiles. A promising approach is to use an electric car, known as a combustion motor replacement. In order to determine its characteristics, the first step in this research is to model the power flow inside the energy system for electric vehicles[3]-[4]. Because electric vehicles are highly dependent on the finite amount of electrical energy provided by the battery, power flow efficiency is a crucial topic to discuss. Therefore, it needs to be handled effectively. In order to ensure that the amount of electrical energy meets the needs of electric vehicles, the study will track the power flow calculation[5]-[8]. The electrical layout of an off-road electric vehicle model using MATLAB/Simulink software is to get the best power flow response to the electric vehicle energy system.

II. Simulation Design Parameters

The simulation approach was entirely based on existing Simulink and MATLAB Models, which was configured according to the requirements. The main reason behind this approach was to avoid “Reinventing the wheel”which saved us a lot of time and extra energy. We had to do a lot of exploratory research to finalize a step-by step problem solving approach to acquire the required data. Using various graphs and problem solving strategies we have fulfilled this topic in detail and the power train model of formula and off road EV is hence made.
Aiming toward resolving the issues with the previous year’s vehicle, so more emphasis was given on Simulating

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and calculating new values of the Power train department (speed,torque,power) and Electrical Department (Battery Calculations) for reaching the heights of efficiency for the power train. Our team also intended to create a correct Cooling system design simulation and analyze the dynamic response. In order to try to to so, several simulations were conducted to realize the right calculations.

III. ELECTRICAL SPECIFICATION

A. Tractive System

Tractive system consist of Accumulator pack,Accumulator management system,Brake light,Led indicators,Fuse, Kill switch,Master switch,Relays, Motor control unit,DC-DC converter,HVD and wires with their connectors.

i)Shutdown Circuit

This Circuit is responsible for shutting down the Tractive System upon failure of any component. It consists of many sensor-driven automatic as well as manual switches which assists the purpose.

ii)High Voltage System

The HV System consists of the following equipment-

- Li-FePo4(Formula)
- Li-NMC(E-Baja) Accumulator Pack
- BLDC Electric motor
- Kelly Motor Controller

iii)Accumulator Pack

Purpose: Supply power to the entire Tractive System

Status:Research for improving the efficiency of existing battery pack by modifying the Accumulator Management and Charging techniques.

For research purposes I am referring to the design strategy of University of Wisconsin-Madison.

Next Steps: modifying the existing pack by adding cell temperature monitoring module and adding some extra safety measures to the cell configuration

iv)Accumulator specification

- Accumulator voltage:48V,
- Accumulator capacity:110Ah
- Li-ion cell Nominal voltage-3.2V
- Charge cut-off Voltage-3.6V
- Cut-off Voltage-2V
- Accumulator pack consist of combination of 22 in parallel and 16 in series.
- The cells contain within an en-closer constructed of fibre reinforced plastic. The cell is mounted in a non permanent arrangement as it will be easy for servicing and access. Accumulator container is equipped with at least 2 AIR & 1 Fuse . It also include AMS with embedded Master and Slave modules to monitor cell voltages. MCU also embedded Thyristor module to regulate the voltage supply to the Motor.

B. Safety Device

i)Accumulator Isolation Relay

TWO KILOVAC EV200 AIRs are used in the system.

each one is connected to the battery positive and negative terminals respectively.Its rated at 500A at 12v.The AIRs are connected in parallel with each other.It is of normally open type relay.Operating temperature -40 degree to 85
degree.

ii)Brake System Plausibility Device (BSPD)

Non programmable.Disconnects AIRS when throttle>10%, and brakes are activated.Opens AIRS circuit.AIRS remain open until power cycle.

iii)Brake light:

Must be red and Visible in sunlight.Must be rectangular/triangular/round.Located between wheel center line/shoulder of driver.

D. Kelly DC to DC converter Specifications

- Nominal input voltage: DC 48V, 60V, 72V
- Output voltage: DC 13.5V under 70℃ or DC 12.2V above 70℃
- Operating voltage range: 40V-100V
- Output current: 30A
- Output power: 400W
- Operating Temperature Range: -20℃ to 90℃ (case temperature)
- Full - load efficiency: ≥93%
- Ripple coefficient: ≤1%
- Weight: 2.25lbs

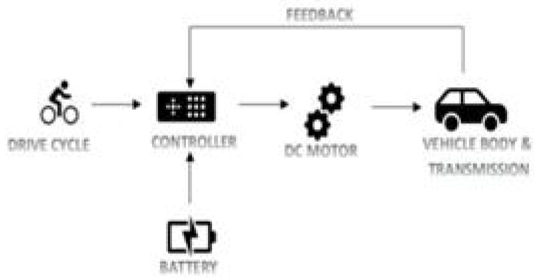


Fig. 1 Block diagram of the overall system

The basic simulink will be derived with respect to the following block diagram.
In the configuration the main blocks are battery, drive cycle, controller, DC motor, vehicle body and transmission and feedback. The driver cycle is the driver input who will ride the vehicle. Here FTP75 drive cycle is used to give the output on how it reacts to the drive cycle. The main purpose to design the EV is to understand the speed of vehicle, calculate SOC discharge rate, distance travelled by vehicle. The SOC block in MATLAB simulink will calculate the SOC, distance is measured by distance and time parameter.

IV. PROBLEM FORMULATION

For the battery charging current I B, the battery management system monitors the battery voltage, SOC, and battery temperature voltage,

$$S = \frac{Ch}{Ch_{nom}}$$

where, S : state of charge; Ch : actual stored “Ah” capacity in the battery; Chnom : the nominal “Ah” capacity of the battery. The battery terminal voltage VB is determined by battery SOC and its impedance.

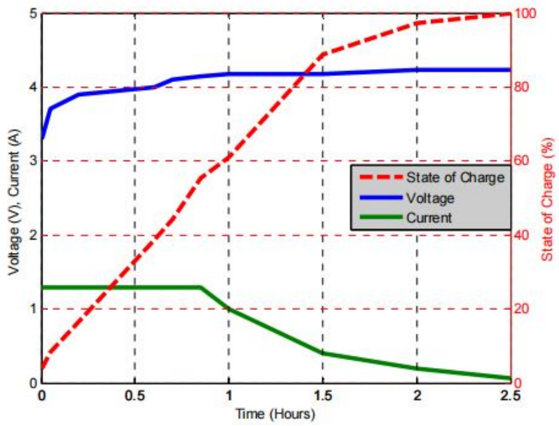


Fig 1: charging characteristic of lithium battery

$$Battery\ Size(Ah) = \frac{watt * hour}{voltage}$$

- Battery size calculation :

  = (3000x8)/48= 500Ah
- Current required to run load: I_1=load(watt)/voltage = 3000/50= 60A
- Battery Charging current: I_2= battery size(Ah)/Hr= 500/10= 50A

  Total current to run load: $I_1 + I_2$

  50+60=110A
- Output power

W=2pi(n)/60 =(2x3.14x2400)/60

= 251 W

P_{out}= T ×W= 251×12= 3000 W approx.

P_{in}= V×I= 48×110= 5280 W

- Efficiency= P_{out}/P_{in} = 55%

V. Simulink Result Analysis

The current flows to the dc motor through the battery through the dc power converter to drive the motor. The controller will control the voltage . the controller will run by the instruction given by the driver input and will run the motor at required rpm.

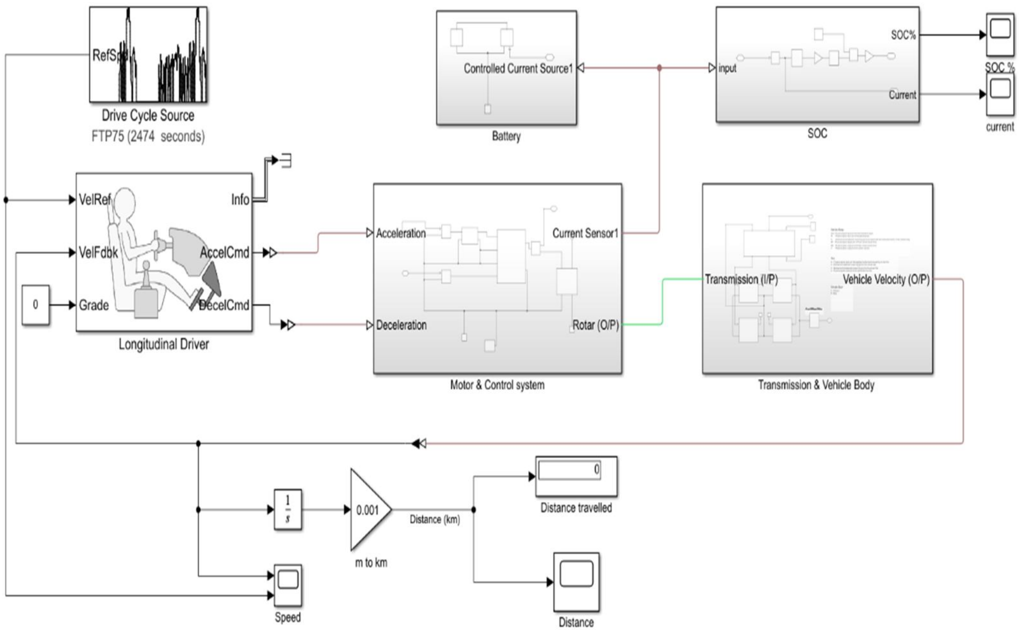


Fig. 2 Simplified configuration of Electric vehicle

All these components are available in the Simscape electrical components library so they need a connection to the solver configuration block which helps solve the simulation.The majority of blocks are Simscape blocks. It convert the physical signal from Simscape block to Simulink signal.

Initially it was set to 90% charge and after running for 1000s the final charge is around 55%.

The distance obtained for a given FTP75 drive cycle with80Ah battery capacity is able to cover say 10km distance for 80Ah battery capacity.

Distance Travelled The distance obtained for a given FTP75 drive cycle with80Ah battery capacity is able to cover 11.14km distance

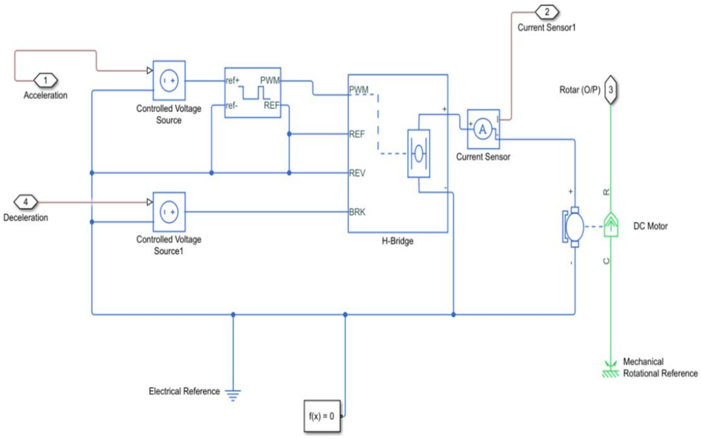


Fig 3: Motor controller design

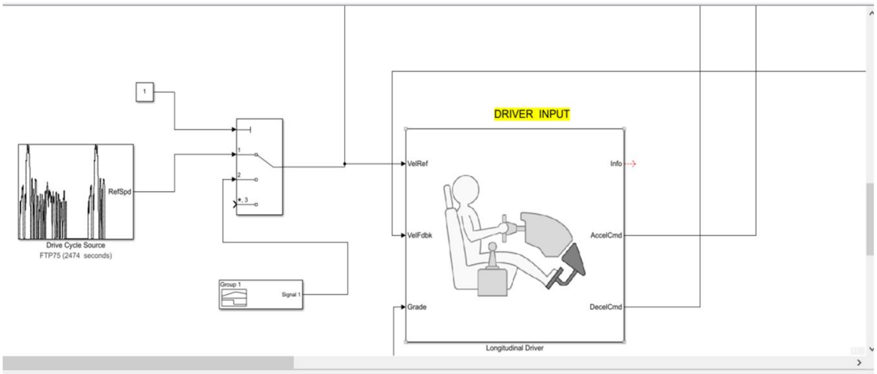


Fig 4: Driver input

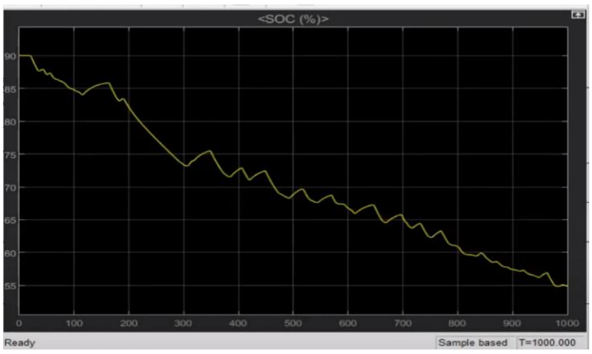


Fig.4 State of charge vs time

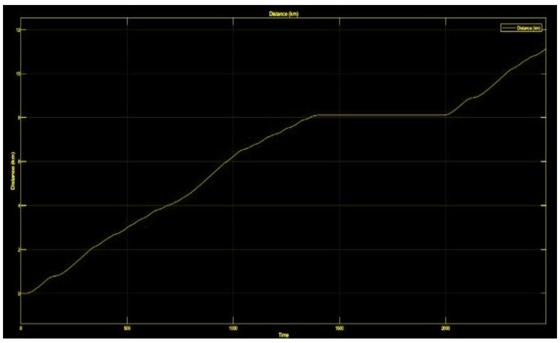
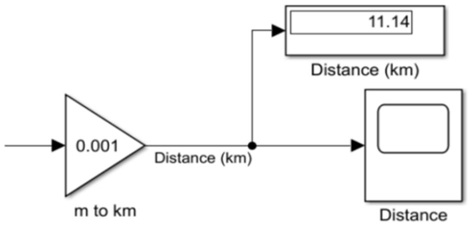


Fig. 5 Distance travelled vs time



VI. CONCLUSION

The EV is created by MATLAB simulink and it is obtained for a drive cycle by FTP75 driver.It can be tested for any drive cycle by selecting the drive cycle block. It can travel 11.14 km by the presence of 80Ah battery capacity. It will travel further more distance if the battery capacity has been enhanced. However, it should be taken into account considering space and cost in the real time.
Making the actual model is made simpler by modelling the EV prototype system. The battery life of an EV can be estimated using this prototype. The model can be used to assess the efficiency of an EV during startup or constant-speed operation.

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