SIMULATION AND MODELLING OF HYBRID ELECTRIC VEHICLE

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Abstract— **Automobiles are an integral part of our everyday lives. Conventional vehicles are the primary cause of urban pollution by late century. The world will eventually encounter an acute energy crisis if we do not focus on alternative energy sources and transportation modes. Therefore, the international community toward developing low-emission (hybrid electric) and zero-emission (electric) vehicles to replace conventional internal combustion (IC) engine vehicles. Several auto industries have started marketing electric and hybrid electric vehicles. Furthermore, the gradual replacement of the hydraulically driven actuators by electrically driven actuators. The EVs.Modelling and simulation in Matlab-Simulink are of great value in investigating the energy flow, performance and efficiency of the EV drivetrain. The design of the EV model presented in this paper, however, is indeed a basic model. There are still many opportunities for augmentation to establish a good EV model which will form the foundation for further research and development. Modelling and simulation are significant for automotive designers to find the best energy control strategy and exact component size, and to minimize the use of energy because prototyping and testing are expensive and complicated operations.Good design leads to a reasonable compromise among flexibility, model simplicity, computational load and accurate representation of the components.**

Key Words: Electric Vehicle (EVs), Hybrid Electric Vehicles (HEVS), Actuators, Matlab- Simulink and Drivetrain.

I. INTRODUCTION

Automobiles are an integral part of our day-to-day day lives and the development of internal combustion engine automobiles is one of the biggest achievements of modern technology. However, the highly advanced automotive industry and the increasingly large number of automobiles in use around the world are causing serious troubles for the environment and hydrocarbon resources. The deteriorating air quality, global warming issues, and depleting petroleum resources are becoming serious threats to modern life. Conventional vehicles are the primary cause of urban pollution by late century. The electric vehicle's modelling and simulation in Matlab-Simulink are of great value in investigating the energy flow, performance and efficiency of the EV drivetrain. Modelling and simulation are important for automotive designers to discover the best energy control strategy and exact component size, and to minimize the use of energy because prototyping and testing are costly and complicated operations. Electricity as an energy
vector for propulsion of vehicles offers the possibility of replacing oil with a wide variety of primary energy sources. This could ensure the security of energy supply and the general use of renewable and carbon-free energy sources in the transport sector, which could contribute to the EU & UN's objectives of reducing carbon dioxide emissions. Electric vehicles emit no tailpipe carbon-dioxide (CO2) and other pollutants such as nitrogen monoxide (NO), nitrogen dioxide (NO2), non-methane hydrocarbons (NMHC) and particulate matter (PM) at the point of use. Electric vehicles exhibit quiet and smooth operation and consequently create low noise and vibration. Road vehicles emit significant air-borne pollution, for example in a country like USA, 18% of suspended particulates, 27% of the volatile organic compounds, 28% of Pb, 32% of nitrogen oxides, and 62% of CO. Vehicles conjointly unharness twenty fifth of America's energy-related dioxide, the principle greenhouse gas. World pollution numbers still grow even sooner as voluminous individuals gain access to public and private transportation. Electrification of our energy economy and the rise of automotive transportation are two of the most noteable technological revolutions of the twentieth century. Exemplifying this enormous change in the lifestyle due to growth in fossil energy supplies. From negligible energy markets within the 1900, electrical generation now accounts for 34% of the primary energy consumption in the United States, while transportation consumes 27% of the energy supply. Increased fossil fuel use has financed energy expansions: coal and natural gas provide more than 65% of the energy consumed to generate the nation's electricity, while refined crude oil fuels virtually all

the 250 million vehicles now cruising the U.S. roadways. Renewable energy, however, provides less than 2% of the energy used in either market. The electricity and transportation energy revolution of the decade has affected many totally different and huge non-overlapping markets. Electricity is employed extensively within the industrial, industrial and residential sectors, but it barely supplies an iota of energy to the transportation markets. On the other hand oil contributes solely third-dimensional of the energy input for electricity. Oil consumption for the purpose of transportation contributes to merely 3% of the energy input for electricity. The present rate of reliance and use of fossil fuels for electrification or transportation is 100,000 times faster than the rate at which they are being created by natural forces. As the readily exploited fuels continue to be used, the fossil fuels are becoming costlier and difficult to extract. In order to transform the demands on the development of

energy systems based on renewable resources, it is important to find an alternative to fossil fuels. Little progress has been created in victimization electricity generated from a centralized facility for transportation functions. In 1900, the quantity of electrical cars outnumbered the gasoline cars by nearly an element of 2. In addition to being less polluting, the electric cars in 1900 were silent machines. As favorites of the urban social elite, the electric cars were the cars of choice as they did not require the difficult and rather dangerous hand crank starters. This led to the development of electric vehicles (EVs) by more than 100 EV manufacturers. However, the load of those vehicles, long recharging time, and poor durability of electric barriers reduced the ability of electric cars to gain a long-term market presence. One kg of gasoline contained a chemical energy equivalent of 100 kg of Pb-acid batteries. Refueling the car with gasoline required only minutes, supplies of gasoline seemed to be limitless, and the long-distance delivery of goods and passengers was relatively cheap and easy. This led to the virtual disappearance of electrical cars by 1920.

2. ELECTRIC VEHICLE

As electric vehicles become capable replacements for sustainable and cleaner energy emissions in transportation, the modelling and simulation of electric vehicles has engrossed increasing attention from researchers. This paper presents a simulation model of a full electric vehicle on the Matlab-Simulink platform to inspect power flow during motoring and regeneration. The drive train components consist of a motor, a battery, a motor controller and a battery controller; modelled according to their mathematical equations. All simulation results are plotted and conversed. The torque and speed conditions during motoring and regeneration were used to determine the energy flow, and performance of the drive. This study forms the basis for further research and development.

The drive train consists of six components: the electrical motor, power electronics, battery, motor controller, battery controller and vehicle interface. The vehicle interface delivers the interface for the sensors and controls which communicate with the motor controller and battery controller. The motor controller normally controls the power delivered to the motor, while the battery controller controls the power from the battery. The battery is for energy storage, usually lithium-ion cells which provide more than 200 V and

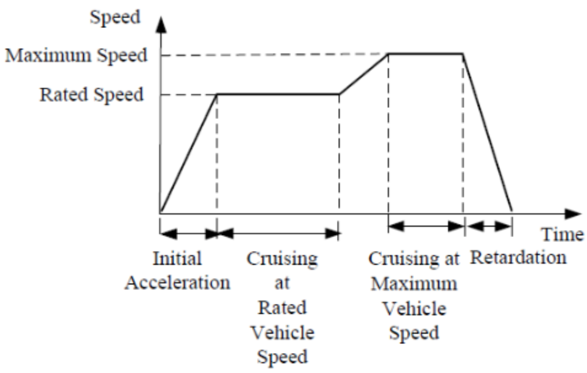
high current to the power electronics. The power electronics influence the voltage, current and frequency provided to suit the motor requirements.

The power requirement during the 100 s simulation time is calculated from the input road speed and road torque data from the driving cycle and is plotted in Figure. The positive power is developed when both speed and torque are positive, note that the motor is operating in forward motion (1st Quadrant operation). However, when the torque becomes negative during positive speed, the motor switches into the 4th Quadrant operating region and acts as a generator.

Power Train and Drive Cycles

Power Train and Drive Cycles The power train of EVs consists of Electric Motor (EM). The first step towards the design of the power train is to determine the power ratings of the motor used in the EV drivetrain is to ascertain the motor specifications. These specifications are determined making use of the drive cycle the vehicle operates on and the vehicle dynamic equation for tractive force calculation. The design constraints set on the drivetrain like the initial acceleration time, the value of the cruising at rated vehicle speed, and the value of the cruising at maximum vehicle speed affects the specification of the induction motor. Finally, the tractive force required to propel the vehicle to the drive cycle chosen gives the necessary motor specifications used in the drivetrain. The design constraints of power train of the vehicle are listed below and the vehicle operating regions are shown in figure.

i. Initial acceleration.
ii. Cruising at rated vehicle speed.
iii. Cruising at maximum vehicle speed.
iv. Retardation.



3.REVIEW OF ELECTRIC VEHICLE TECHNOLOGY AND ITS APPLICATIONS

With the increasingly severe environmental problems around the world, exploitation of clean and renewable energy has been a crucial topic. As indispensable transportation in modern society, vehicles are ubiquitous but also one of the main sources of pollutants. Because of their status, it is almost impossible to decrease the bulk of vehicles. One solution to dropping emissions is the electric vehicle. Overall, the electric vehicle is more energy efficient, environmentally friendly, and cleaner than the vehicle that relies on fossil-fuels, especially when smart grids have become omnipresent. By promoting the electric vehicle, the environmental and economic costs of vehicles can be significantly reduced. Hence, the electric vehicle has attracted the attention of academia as well as industry in the recent decades. With the development of the electric vehicle, the techniques of charging piles-which are an essential component in the electric transportation system- have rapidly progressed as well. Most of the automobile manufacturers around the world have paid a large amount of financial resource to the research of charging piles, since the charging technique is, to some extent, key to the success of the electric vehicle.

4.A MATLAB-BASED MODELING AND SIMULATION PACKAGE FOR ELECTRIC AND HYBRID ELECTRIC VEHICLE DESIGN

The purely electric vehicles (EV’s) are a promising technology for the long-range goal of energy efficiency and reduced atmospheric pollution, their limited range and lack of supporting infrastructure may hinder their public acceptance. Hybrid vehicles offer the promise of higher energy efficiency and reduced emissions when compared with conventional automobiles, but they can also be designed to overcome the range limitations inherent in a purely electric automobile by utilizing two distinct energy sources for propulsion. With hybrid vehicles, energy is stored as a petroleum fuel and in an electrical storage device, such as a battery pack, and is converted to mechanical energy by an internal combustion engine (ICE) and electric motor, respectively. The electric motor is used to improve energy efficiency and vehicle emissions while the ICE provides extended range capability.

Computer modeling and simulation can be used to reduce the expense and length of the design cycle of hybrid vehicles by testing configurations and energy management strategies before prototype construction begins. V-Elph is a system-level modeling, simulation, and analysis package developed at Texas A&M University using Matlab/Simulink to study issues related to EV and HEV design such as energy efficiency, fuel economy, and vehicle emissions. V-Elph facilitates in-depth studies of power plant configurations, component sizing, energy management strategies, and the optimization of important component parameters for several types of hybrid or electric configuration or energy management strategy. It uses visual programming techniques, allowing the user to quickly change architectures, parameters, and to view output data graphically. It also includes detailed models that were developed at Texas A&M University of electric motors, internal combustion engines, and batteries. This paper discusses the methodology for designing system level vehicles using the V-Elph package. An EV, a series HEV, a parallel EV, and a conventional ICE driven drive train have been designed using the simulation package

5. MASTER THESIS ON ‘SIMULATION OF ELECTRIC VEHICLE INCLUDING DIFFERENT POWER TRAIN COMPONENTS

The rate of consumption of the fuel is simply making its way more than the rate of productions, that inevitably can reach on a point where it'll be fully exhausted with no additional fossil fuels to satisfy the demand. Imagine life with mobile phones, but without any electricity to charge it, appears like historical periods, not a pretty picture to imagine. other outstanding concern related to the exhaustible use of fuel is environmental problems. Impact of carbon dioxide gas on the surroundings isn't new to be known. it's been first theorized by noble prize laureate Svante Arrhenius back in 1896. However, the emission of carbon dioxide may be divided majorly into two causes: Natural Phenomena and anthropogenic. natural phenomenon like volcanic aerosol and anthropogenic economic activities has been seen as important contributors to temperature rise over past years, apparently resulting in temperature rise leading to glacier meltdown.

A. Electric Propulsion

Electric Propulsion is nothing but a heart of electrical Vehicle. It consists of electric Machine, Power Converters, and electronic converters. the main workforce to mobilize vehicle comes from electrical machines used for a purpose. Power converter’s function is to supply electrical input according to the instantaneous requirement of machine consistent with the coupled load. electronic converter provides control signals to the power converter consistent with the command given by the driver. The scope of EVs traveled side by side as with introduction and advancement of semiconductor switches devices. electric machines have been in use with more than a century due to its relatively characteristic to deliver consistently with the load. The efficiency of electrical machines is typically more than 90%, which in comparison to the IC engine is far higher. The electrical machine converts electrical to mechanical energy and vice versa. electrical energy is simply not efficient but also regenerative in nature. in the braking mode, an electrical machine can recuperate energy by extracting kinetic energy from the wheel (generating mode) and store in the energy accumulators, either in Battery (High energy density) /or Ultracapacitor (High Power Density). practically only some of the energy is recovered since irreversible energy conversion takes place in the form of mechanical losses. both families of machines have their pros and cons and found their application according to the load requirement. DC machines were incorporated in the 1980's decade because of its torque to load characteristics and controllability. Despite such fine traits, DC machine is no longer being preferred due to its size and maintenance requirement. Nowadays, latest vehicles manufacturers are using AC and brushless motors, as well as Induction Motors, Switched Reluctance Motor and permanent magnet Motors.

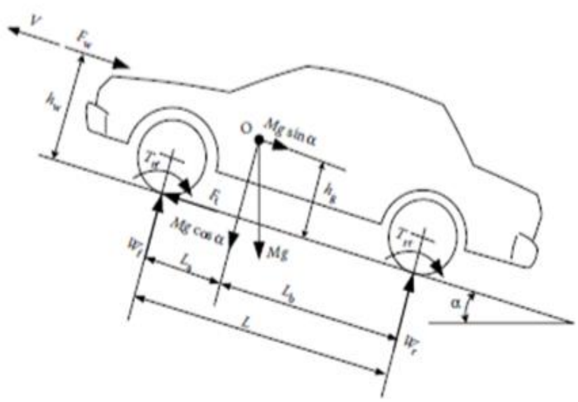
B. Electric Power Source

The two main energy sources and storage used in this work are, Electrochemical batteries and Ultra capacitor (also known as Super capacitor). Also known as electric batteries in general, are made by connecting individual cells in order to get a specific standard voltage at their terminals. Batteries are energy devices which converts chemical energy to electrical energy, hence the name electrochemical device. Batteries now a days plays an important role in as an energy producing source as well as energy storage devices. As we mentioned batteries are primarily made up of individual cells by a suitable connection, therefore we will now focus on the cells to have further understanding of batteries.

C. Vehicle kinetics

These equations govern the total force acting on a vehicle while in motion. A vehicle basically has to overcome these forces to keep moving steadily.

Calculation of vehicle rolling uphill



Where,
FgxT=Gravitational force,
FROLL = Rolling resistance,
FAD = Aerodynamic drag force,
xT is tangential direction on the roadways. Force Due To Gravity

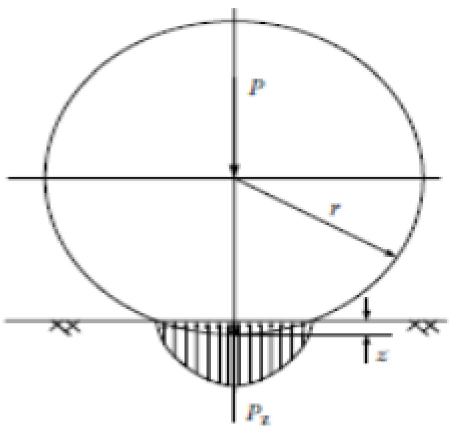
When a vehicle goes up or down a slope, its weight produces a component that is always directed in the downward direction. This component either opposes the forward motion(grade climbing) or helps the forward motion (grade descending). In vehicle performance analysis, only uphill operation is considered. This grading force is usually called grading resistance.

Grading resistance, can be expressed as
Fg = Mg sin α.
Where,
m = mass of the vehicle,
g = acceleration due to gravity,
β = slope angle (grade angle) with respect to horizon.

Rolling Resistance Force

The rolling resistance of tires on hard surfaces is primarily caused by hysteresis in the tire materials. Figure shows a tire at standstill, on which a force, P, is acting at its center. The pressure in the contact area between the tire and ground is distributed symmetrically to the central line and the resultant reaction force, Pz, is aligned to P. When the tire is rolling, the leading half of the contact area is loading and the trailing half is unloading. Consequently, hysteresis causes an asymmetric distribution of the ground reaction forces. The pressure in the leading half of the contact area is larger than that in the trailing half. This phenomenon results in the ground reaction force shifting forward somewhat. This forwardly shifted ground reaction force, with the normal load acting on the wheel center, creates a moment, which opposes rolling of the wheel. On soft surfaces, the rolling resistance is primarily caused by deformation of the ground surface. The ground reaction force almost completely shifts to the leading half.

Calculation of rolling resistance force



Where,
Crr = coefficient of rolling resistance, (~ 0.01 to 0.035, for tires on road)
m = mass of vehicle
g = acceleration due to gravity
c. Aerodynamic Drag:

A vehicle traveling at a particular speed in air encounters a force resisting its motion. This force is referred to as aerodynamic drag. It mainly results from two components: shape drag and skin friction. It consists of shape drag (90%) and skin drag. Shape drag: The forward motion of the vehicle pushes the air in front of it. However, the air cannot instantaneously
move out of the way and its pressure is thus increased, resulting in high air pressure. In addition, the air behind the vehicle cannot instantaneously fill the space left by the forward motion of the vehicle. This creates a zone of low air pressure. The motion of the vehicle, therefore, creates two zones of pressure that oppose the motion by pushing (high pressure in front) and pulling it backwards (low pressure at the back). The resulting force on the vehicle is the shape drag. The name “shape drag” comes from the fact that this drag is completely determined by the shape of the vehicle body. Skin friction: Air close to the skin of the vehicle

moves almost at the speed of the vehicle while air away from the vehicle remains still. In between, air molecules move at a wide range of speeds. The difference in speed between two air molecules produces a friction that results in the second component of aerodynamic drag. Aerodynamic drag is a function of vehicle speed V, vehicle frontal area, Af , shape of the vehicle body, and air density, ρ:

$$F_w = 1/2 \rho A_f C_D (V - V_w)^2,$$

where CD is the aerodynamic drag coefficient that characterizes the shape of the vehicle body and Vw is component of the wind speed on the vehicle moving direction, which has a positive sign when this component is in the same direction of the moving vehicle and a negative sign when it is opposite to the vehicle speed. The aerodynamic drag coefficients for typical vehicle body shapes are shown in Figure.

Where,

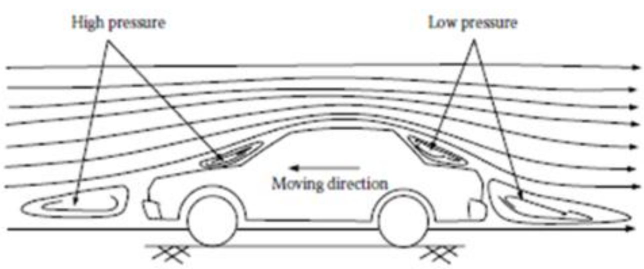
ρ = air density,

A = frontal area,

Cd = aerodynamic drag coefficient, (depends upon design of the vehicle)

V = vehicle longitudinal speed,

Vw = wind speed



Aerodynamic drag coefficients for a typical vehicle

The basic block diagram of our project is given in Fig

6. SIMULATION

As it is shown above the figure contains two propulsion sources which is the ICE and the Motor which is coupled to the gear box. The motor is supplied by the battery pack. The battery pack often produces voltage, which is likely to be lesser than required, therefore there is an inclusion of boost converter into the system which amplifies the dc voltage. This voltage is then converted to the ac variable form through the dc-ac inverter for the motor. The generator is also employed here to support the battery against nonlinearities. The Electronic Control Unit (ECU) sends gating signals to all the components in the electrical system of the battery. It is the brain of the system that send signals to and fro in the system for overall controllability.

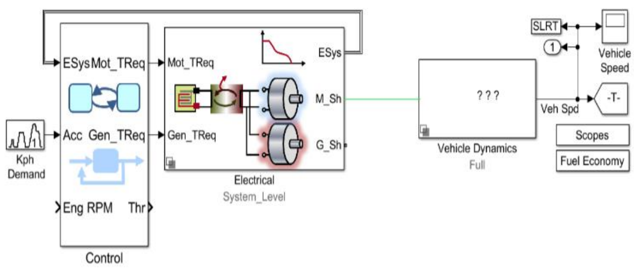
The end system of the model is the vehicle kinetics which is governed by various friction and air drag the vehicle will encounter when it is in motion.

Electric Motor Modelling

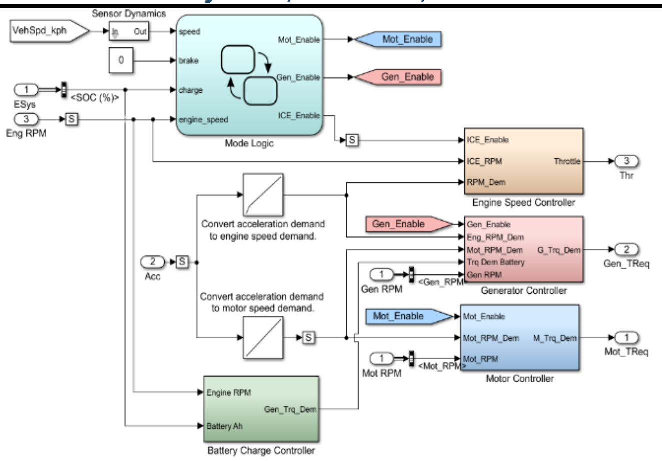
There are three main approaches of modelling an electric machine for hybrid drive purposes. The first approach uses neglects the dynamics of the machine and inverter, and instead uses efficiency maps to determine the electrical power consumed given a certain mechanical power load. The second method takes the electrical dynamics of the machine into consideration using the dq-axis. The third approach takes the electrical dynamics into account, similar to the second approach, but models the actual three-phase current in the electric machine. All three modelling procedures will be discussed below.

Efficiency-Based Modelling of an Electric Machine

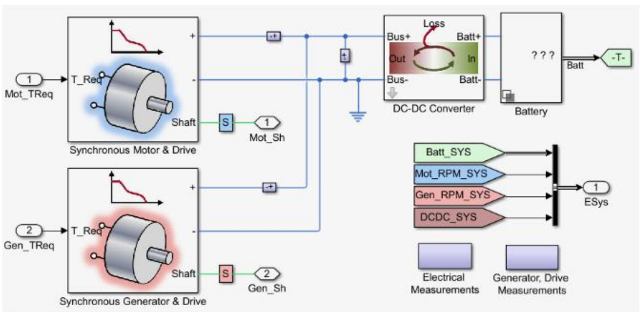
The diagram of the Electrical Differential Systems (EDS) block for the efficiency modelling of an electric machine is shown in Figure



As it is displayed the control of the acceleration and the motor is determined by the control block. The electrical system contains the generator and motor models of the electrical vehicle. In the last block we can see the vehicle dynamics block which shows the power train of the vehicle. The internal diagrams and the different voltage and current reading are displayed in the
below:



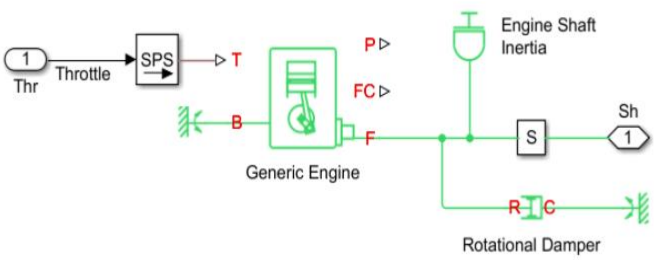
The above figure shows the internal control scheme in the simulation being worked on .In this the vehicle speed is given as input to the speed and the constant input is supplied to the brake input .The charge and the engine is suitable supplied too . the output of this state flow mode logic is the signals that control the generator and the motor, even the signals for the ICE is formulated here .As it is seen in the figure the signals for the battery charge controller is also acquired here . The other three blocks which is the engine speed controller, generator controller and motor controller is supplied with suitable inputs from the mode logic .



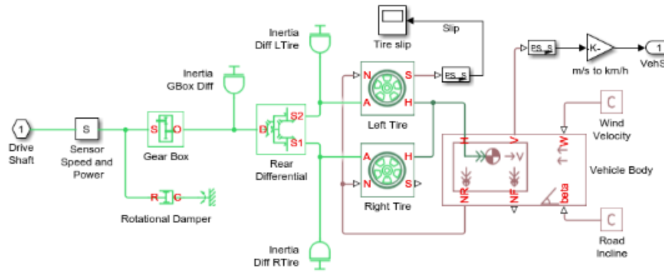
The above figure is the internal blocks of the electrical system of the whole simulation model. It contains the blocks which describe the functionalities of motor and generator which is connected to the dc-dc converter which sneds signals to the battery . The scopes which show the elctrical waveforms are shown in the block named as electrical measurements .

The internal block of the engine contains the generis model of the engine which has the engine shaft inertia attached along with it .A rotational damper is also shown in the figure

.The block showing the letter S is the sensor for the engine.The internal block is shown Below



The power train of the EV is the most interesting of all and the basic blocks and constant are shown below



The code required to run the simulation is stated below :

HEV_Model_HomeDir = pwd;
addpath(pwd);
addpath([pwd '/Libraries/Electrical']);
addpath([pwd '/Libraries/Battery']);
addpath([pwd '/Libraries/Vehicle']);
addpath([pwd '/Images']);
addpath([pwd '/Scripts_Data']);
addpath([pwd '/Reports']);
addpath([pwd '/Power_Quality']);

HEV_Model_PARAM

% FOR VARIABLE INERTIA (PCT TESTS)
if(exist('Libraries\Vehicle')==7)
cd Libraries\Vehicle
if((exist('+TunableMech')==7) && ~exist('TunableMech_lib'))

disp('Building Custom Simscape Library...');
ssc_build TunableMech
disp('Finished Building Library.');
end
cd(HEV_Model_HomeDir)
end

open('HEV_Model_Demo_Script.html')

RESULTS

The various simulated results of the matlab modelling is displayed in this chapter .

The waveforms simulated from the code is displayed below :

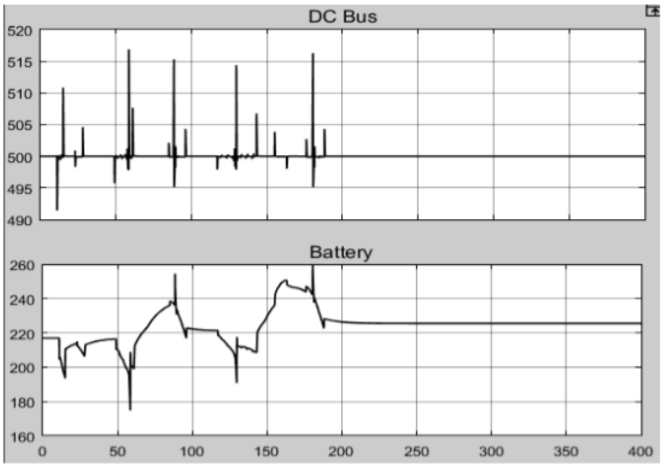


Fig 5.1: The Voltages of the dc bus and the battery

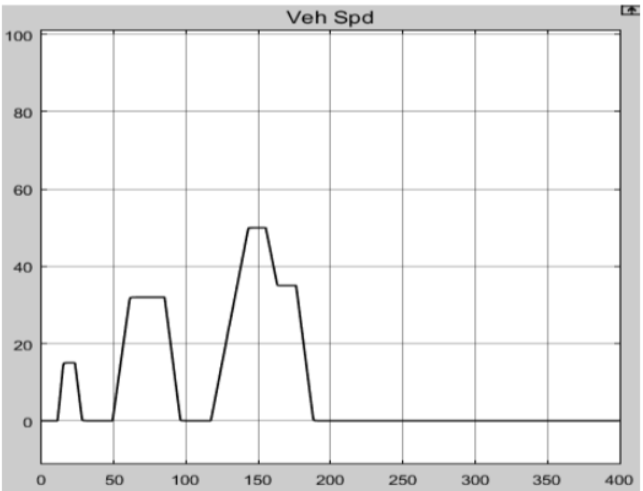


Fig 5.2 : The speed of the vehicle.

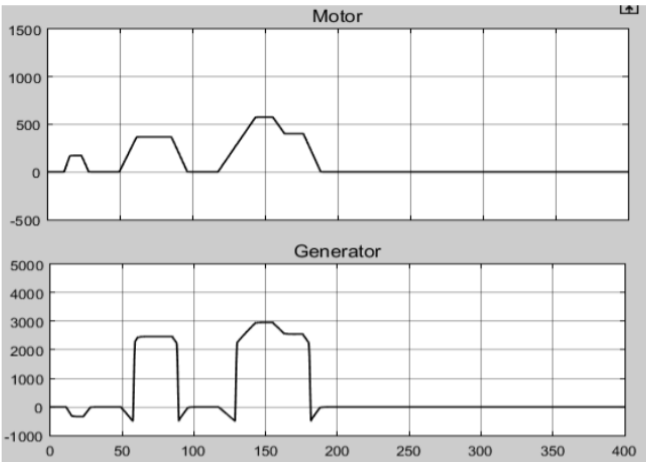


Fig 5.3: The waveform of the motor and generator

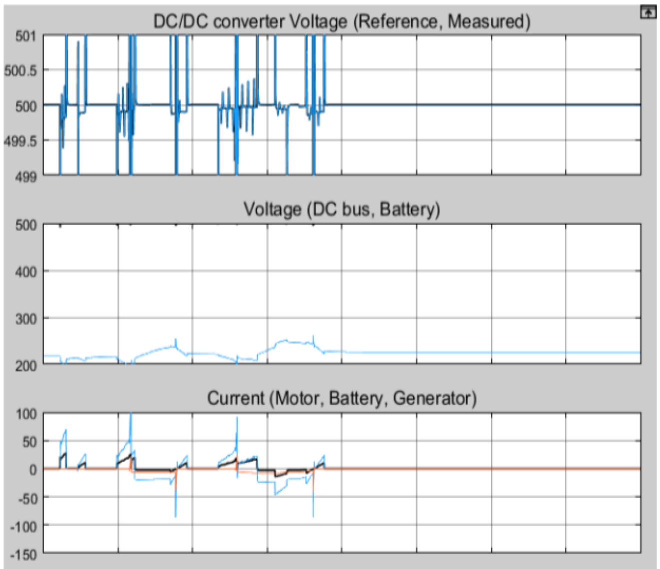


Fig 5.4: Waveforms of converter and V & I of battery

7. CONCLUSION

In the beginning, the main stream of commercial software was studied for electric vehicle simulation and Matlab/Simulink and its toolbox (SimPower System/SimDriveline) were selected to build a EV dynamic simulation model because the tools use physical modeling approach with superior advantages against signal based approach and the developed models can be seemlessly integrated into control design process. The EV model has a configurable structure that combines simulation models associated with deployment and test for different controllers to a single platform. It can do fast simulation to validate vehicle controller design with enough details of dynamic behavior for electrical system. This report discusses battery pack modeling, simulation, using Matlab/Simulink to study to simulate EV design such as energy efficiency, fuel economy, and vehicle emissions. The package uses visual programming techniques, allowing the user to quickly change architectures, parameters, and to view output data graphically. It includes models of electric motors, and batteries. Using the generated outputs, it is possible to determine the exact requirements for the given specifications. As one of the most important part of the electric vehicle design is to clearly determine the specifications for the given target group, this is intended to optimize the vehicle and drive system design, and ultimately uplift the quality of the electric vehicles. The practical implementation has proved its performances in the actual electric vehicle design field. The simulation has well proved that the simulator works according to the requirements and that it is a very useful tool in any vehicle design in scheming battery and the controller, which would be very painstaking and time consuming otherwise. In this paper, we introduce a battery simulation framework, referred to as the virtual battery, to evaluate the performance of batteries during usage in electric vehicles. The proposed modeling technique represents EV subsystem in a compact and modular way. Once these models are developed it is possible to conform, in a straightforward manner, an integrated model that represents the complete vehicle performance. This complete model becomes a helpful tool to verify rapidly any modification on the vehicle's design or in the control strategy, reducing time and development costs. Given the usefulness of the proposal it can be easily modeled for any other EV configuration and understanding the dynamics of electrically driven vehicles. Simulation results are delivered in order to illustrate the multi-domain feature of the complete model. In addition, they help to analyze the battery dynamics when regenerative braking is applied. With this complete model totally validated it would be possible to determine accurately the impact produced by a fault in the batteries onto the rest of the vehicle components and the whole performance under faulty conditions.

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