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ANALYSIS OF BATTERY BASED HYBRID ELECTRIC VEHICLE POWER TRAIN

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ABSTRACT

The paper presents the development of battery based power train models for electric vehicles. The Hybrid Electric Vehicle (HEV) is considered as cleaner and green energy transportation and reduce the Greenhouse Gases (GHG) emission globally. The detailed literature survey is presented along with design of battery based power train models in Matlab with detailed structure. Precisely, the designed work aims at arranging the basic foundation and development of HEV benchmark to be matched in real time simulation. The new power train design is based on the strategy of energy allocation, management and consumption to attain all driving range operations under Urban Dynamometer Driving Schedule (UDDS) driving Cycle. This study focused on the energy-saving of battery electric vehicle for defined driving distance in UDDS driving cycle. The simulation results were analyzed for effective utilizations of battery management system. The developed model will give the benefits of pollution free, less maintenance cost, noise elimination in power train, improved energy management functions, and increased efficiency towards energy savings.

Keywords: hybrid electric vehicle, greenhouse gas, urban dynamo driving schedule, battery management systems.

INTRODUCTION

One of the major issues faced by the world is climatic change due to increasing of GHG emissions and the major emission contributed by the transport. Due to emission many of the government planned for alternative transportation to reduce the environmental pollution [1]. The recent study shows the employing of electric vehicle in global market helps in environmental concerns. The new technologies come in to play for modifying the different models evolved in electric vehicle and hybrid electric vehicle with reference to industrial regulations, standards, environmental factors and global consideration. Recently a study shows the vehicle to grid and grid to vehicle integration done with help of batteries. The general structure of electric vehicle consists of DC/AC/BLDC machines along with different power train models and strategies in addition with battery packs [2]. The fossil fuel operated combustion engine is gradually decreased in the global scenario, compared to advancement of electric vehicle, hybrid electric vehicle which leads to zero emission are increasing as global alternatives [3]. The global auto manufacturers are concentrated in the elimination of internal combustion powered electric vehicles with respect to aggressive bounded timelines [4]. The automobile industry recently reported the development and evolution of EV in the market within 8 years [5]. The EV battery based power train is engaged to reduce the cost of HEV and increasing the performance of the system [6]. There are different power train configurations such as mild hybrid, strong hybrid, plug in hybrid and full battery operated EV is employed in generation of impulsion torque in electric vehicle [7]. Besides, huge resources are being involved in EV technology and cutting off the production cost [8]. Mild hybrid vehicles are not utilized via electric mode in driving mode, it employs the combustion engine [9]. The strong hybrid vehicle is combination of both internal combustion engine and battery packed system allows driving in electric mode, but it requires complex architectural system design and need significant improvement in consumption of fuels [10].

The electric vehicle structure consists of combustion systems along with drives which is replaced by numerous electrically driven accessories. The hybrid drives are classified with reference to various power levels [11] & [12] shown in Table-1.

Table-1. Classification of drives with respect to power levels.

Modes of Operation	Survey	Power levels
Start/Stop	Enable the combustion system to start/stop	1-2 KW/t 14V
Micro hybrid	Works along with regenerative braking Conventional starters are required Belt driven, crankshaft is directly coupled with electric motor	2-5kW/t 48V
Mild hybrid	Not allowed to Electric Driving Allowed only for regeneration and enables the boosting operation	5-15kw/t 48-200V
Full hybrid	Electric driving mode is activated with the help of internal combustion engines along with above mentioned point in to consideration Driving gain is obtained by upshifting point of ICE	>15Kw/t >200V

The hybrid electric drives are classified with reference to coupling methodology [13] & [14] shown in Table-2:

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Table-2. Classification of drives with respect to coupling

Coupling strategy	Survey	Drawbacks/ Observations
Inline Drives	The components arranged in same line of axis The generator coupled to the ICE directly Instead of battery, super capacitors are employed as energy storage systems ICE may be operated with driving requirements or need of instantaneous power	It requires multiple energy conversions The energy loss also associated with drive
Parallel drives	Directly connected (Both electric motor and combustion engine) Only one motor is needed The motor is installed at the output of gearbox to reduce the losses occurred during transmission is the alternative solution. The electric motor helps for compensation during power loss while shifting the gear.	Electric moto and IC engine always rotates in same speed it leads to drag losses Additional Clutch is employed to reduce the losses
Combined Drives	The in-line and parallel drive characteristics are merged together in combined drives. In combined mode, the transmission of first electric machine (Generator) is act as the input and coupled to the second machine (motor) coupled to the internal combustion engine. During the period, batteries will be charged. The serial mode is enabled by disconnecting the coupling of both machine and useful for driving in low power and high dynamic regions.	Rotational speed and operating point of the ICE is resolutely set through the ratio. Possible to minimize the losses
Power-split hybrid drives	The Mechanical energy is transmitted in to two paths of the wheels. In first path, the mechanical power directly transmitted and remaining energy flowing in auxiliary path which consists of two machines (Motor and Generator)	Power loss occurred in power split mode is compared to in-line hybrid is less
Plug-in hybrid	Plug-in hybrid mode means it requires the larger battery pack and electric mode. Efficient motor is utilized	Operating cost is reduced Noiseless driving and emission free

PROPOSED SYSTEM DESIGN

The designed system consists of four vital parts namely, electric motor, generators, battery and DC converters. The power split model is modelled with help of planetary gear subsystems which allocating and combining the mechanical motive force generated by the engine, generator and motor. ICE system is designed with gasoline engine along with governor to control the speed. Vehicle dynamic System is used to model the mechanical fragments of the vehicle. The Energy Management System (EMS) is employed to control the machine with the help of reference signals depicted in Figure-1.

Circuit Description

The combination of series-parallel method is utilized to design the power train of HEV with similar to exiting Toyota car model. The system model is developed with the help of Simdriveline and Simpowersytem. The developed model consists of internal combustion Engine and motor and similarly it helps to reduce the environmental pollution to increase the drive train efficiency. In spite of advantages of employing motor helps to achieve high power at low speed and ICE helps to take concern on dynamic performance of the vehicle.

The designed electrical system consists of motor, generator, DC converter and battery shown in Table-3.

Table-3. Specifications of electric subsystems.

Subsystems	Specifications
Electric Motor PMSM	$450V_{dc}$, 45kW 8 Pole and Sailent type rotor Max speed- 4500rpm
Generator	$450V_{dc}$, Pole-2, 25 kW, max speed= 12000
Battery (Nickel Hydride)	$300V_{dc}$, 6.5AH, 18kW
Boost Converter (DC/DC)	$300V_{dc}$

The mechanical motive force from the engine is transferred with the help of planetary device by allocating and combining the action of motor and generator. By the way it splits the power with help of planetary gear system.

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The gasoline fuel engine is modelled to give 5000rpm along with speed governor. The input of throttle is allotted between 0 & 1. Also, it specified the torque derived from the engine for maximum level. The engine speed is indirectly controlled with help of signal.

The mechanical portions of the EV is modelled with help of VDS,

- The differential divides the input torque into two wheels with equal torques, while the single reduction gear reduces the motor's speed while boosting torque.
- The tyre dynamics represent the force delivered to the ground.
- The vehicle dynamics indicate how the entire system moves.
- All mechanical system losses are simulated using the viscous friction model.

In order to distribute power from these sources, electric motor drive, electric generator drive, and internal combustion engine are used to generate the reference signal. The accelerator operates between -100 % and 100%, and the observed hybrid electric vehicle speed are used to calculate the values of signal. It's important to remember that position of positive brake relates the negative accelerator position.

The State of Charge of the battery is kept between 100 and 95 % and maintained the defined level by the BMS. The battery controlled the requirement of power helps to inhibit the voltage collapse.

The reference power of the motor is controlled by hybrid management system (HMS) and the power demand is monitored with help of HMS. In addition to that torque and engine speed is controlled.

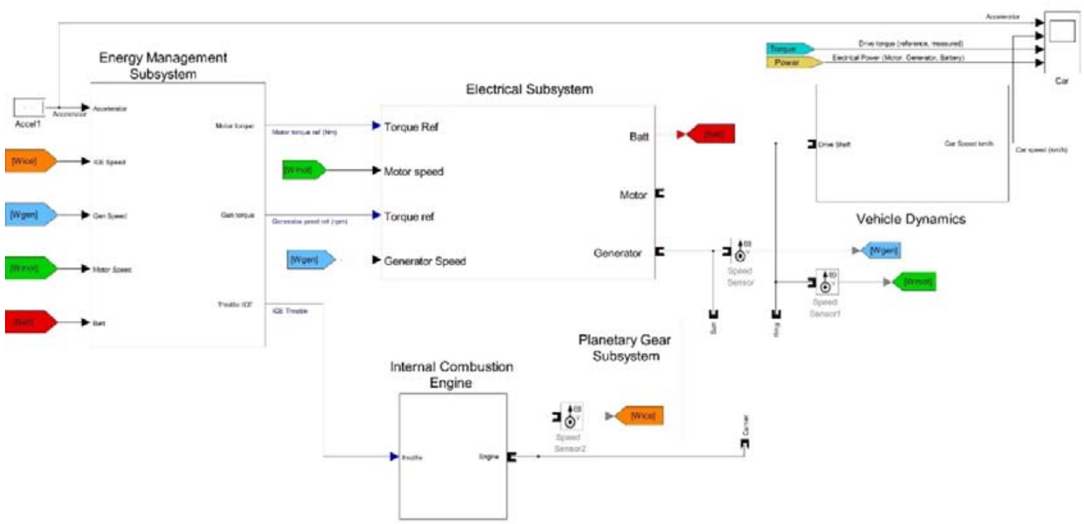

Figure-1. Proposed overall design using Matlab.

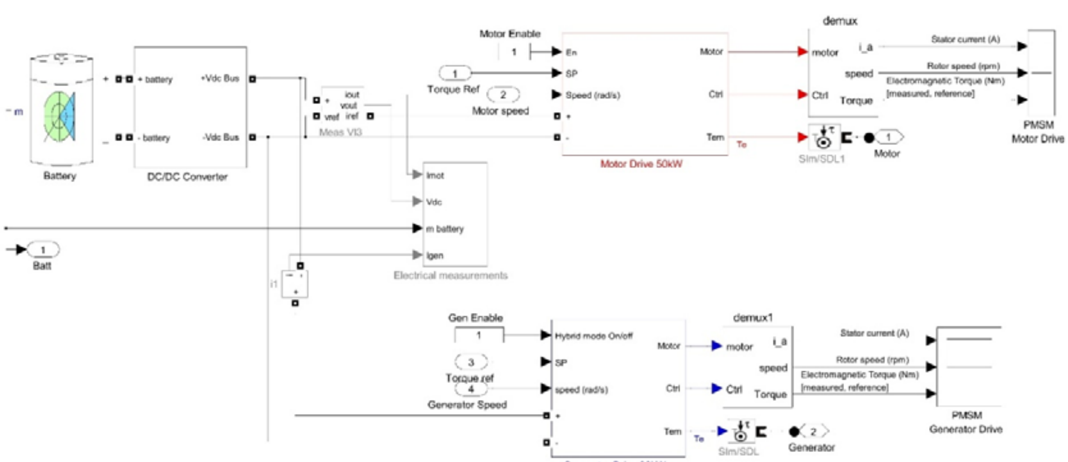

Figure-2. Simplified electrical system design with battery using Matlab.

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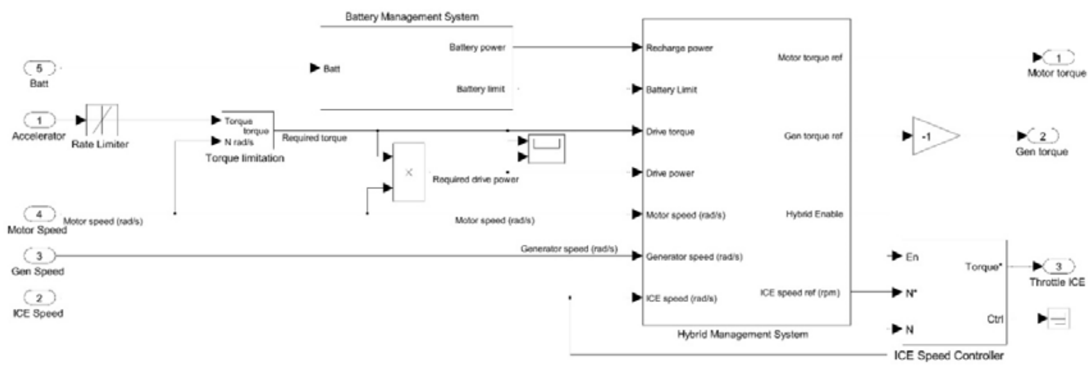

Figure-3. Hybrid battery management system design.

RESULTS AND DISCUSSIONS

The simulation is done with Urban Dynamometer Driving Schedule (UDDS) driving range to test the battery based energy management system. This pattern is proposed to access the various road models. In this system, the battery state of charge (SoC) is diminished from 70% to 40% at the preliminary stage. The actual and demands speed of the car are assumed to be identical. The characteristics of UDDS driving parameters are shown in Table-4.

Table-4. UDDS driving characteristics cycles.

Parameter	Values
Total Distance	1409 km
Total Time	12.05 s
Maximum speed	92.56 km
Acceleration Average	0.536 (m/s^2)
Deceleration Average	- 0.579 (m/s^2)

Figure-4 shows the result of simulated car for 20s. The observed operation during simulation shown in Table-4. The battery management system performance depicted in Figure-5.

Table-5. Observations of simulated battery operated HEV power train.

Simulation Time	Observed Simulated results
t=0S	Hasten the pedal to 70%. The required energy is lower than the specified level (10kW). HEV operated with the help of battery. Initially, Battery SoC sets to 75%
t=1.2s	The required power is above than the actual power of 10kW, ICE distributes the power with the help of battery to operate the hybrid electric vehicle. It will triggers to operate in hybrid and acceleration mode.
t=3.5s	Crushing mode is activated by releasing the pedal to 15%. Instantly the ICE not able to change its operation, so the battery operated to absorb the excessive power by the way it reduces the torque.
t=4.5s	The working of the generator is stopped. The battery supplies the required energy
t= 8s	Again the pedal raised to 80% to activate the acceleration mode. The maximum power is distributed by generator.
t=12s	State of charge of the battery reaches to 40%, battery needs recharging, so the generated power will shared between motor and battery with the help of generator.
t=16s	Braking is activated by switching off the generator, instantly the pedal will reach the value of -45%. During this condition , the power generated by regenerative braking will be absorbed by the battery

Figure-6 Shows the UDDS driving cycle with actual and demand speeds of the EV along with the plots of the battery and the motor. During simulation, the traction energy demand was 74.8% and energy of regenerative braking increases by 30% in UDDS driving cycle.

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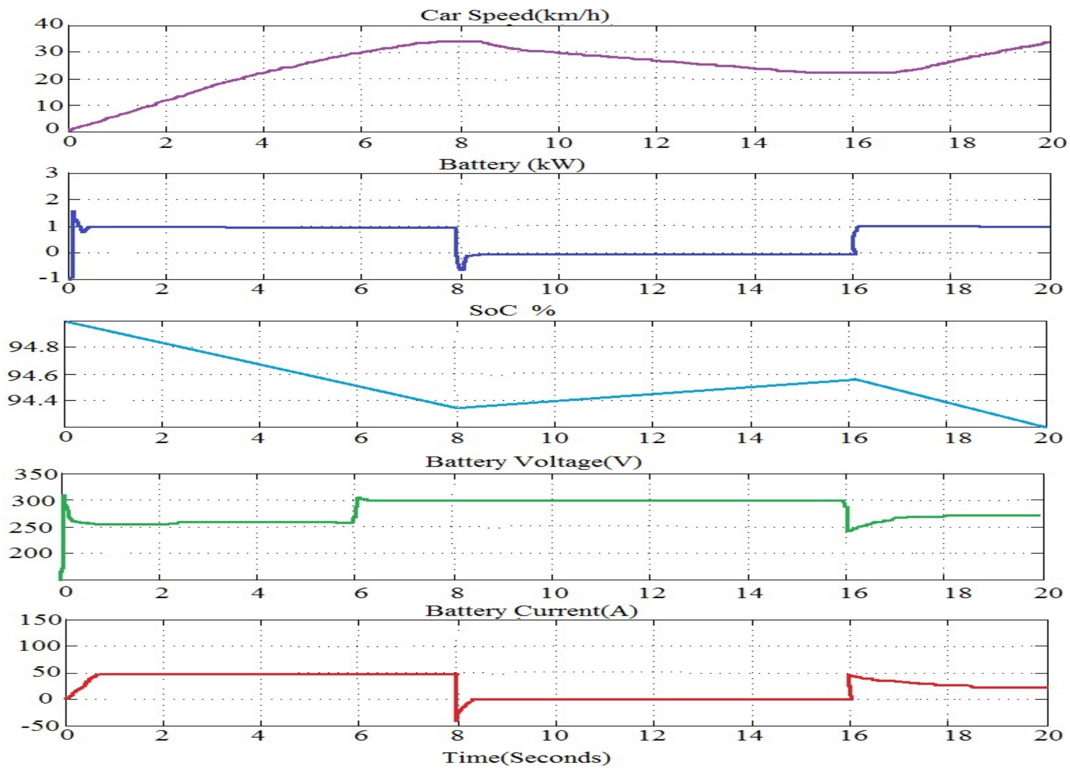

Figure-4. Simulated parameters for EV car.

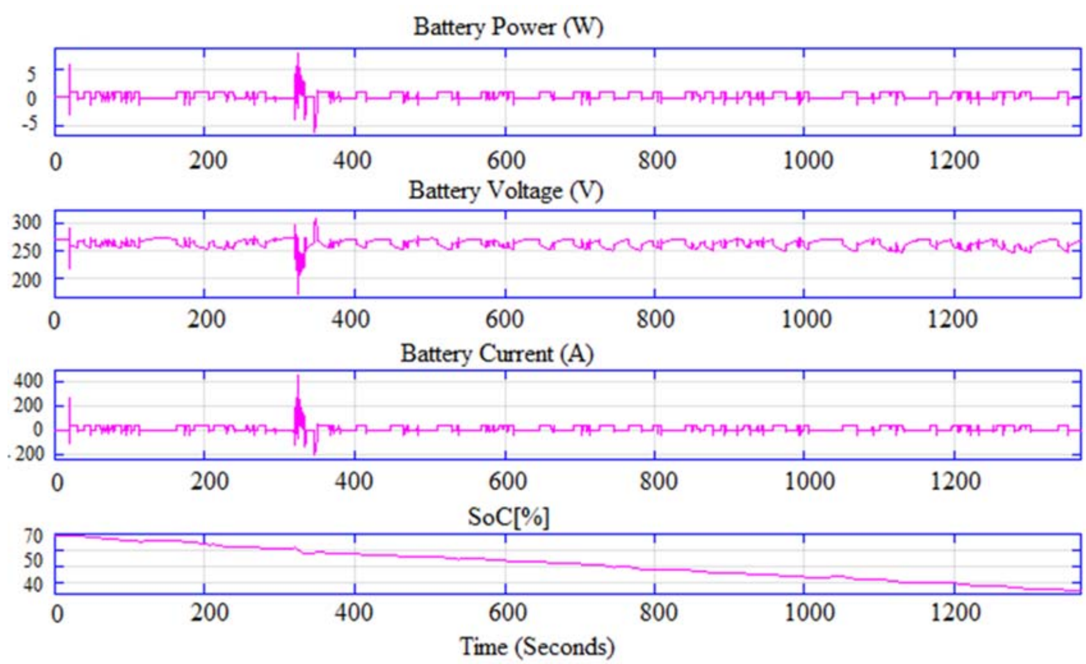

Figure-5. Waveforms of Battery management system.

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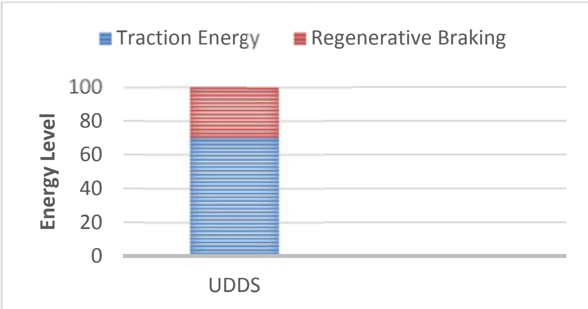

Figure-6. Energy demand in UDDS driving cycle.

CONCLUSIONS

The DC bus voltage of the entire system is well regulated at 450 V and maintained throughout the simulation. Throughout the simulation, that the Willis relation is equal to -2.6 is observed and the planetary gear's power law is equal to 0. The modelling and simulation provides the basic ideas for designing power train components for hybrid electric vehicle using Matlab/Simulink. In this battery management strategy is analyzed in MATLAB environment. According to the requirements of energy for the specified driving cycle, battery rating is chosen to match the need and demand. The loss components of the EV car depends upon the battery management system during driving operations. The designed model is tested under UDDS to test the efficiency of the designed power train model. The result shows that the battery charging and discharging cycle is effectively utilized in the tested driving range. In future, the work will be carried out in design based research to obtain the final HEV design through SIL and HIL methodology.

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