IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⁜ Impact Factor 7.105 ⁜ Vol. 9, Issue 5, May 2022

DOI: 10.17148/IARJSET.2022.9545

Quasistatic Modeling and Simulation of an HEV(Electric Drivetrain)

Fahim Vazir[1], Keshav Thakur[2], Danish Shaikh[3], Shraddha Walvekar [4]

Student, Department of Mechanical Engineering, Trinity College of Engineering and Research, Pune, India [1,2,3,4]

Abstract: The rapid use of gasoline, as well as the increase in environmental damage caused by it, provided a powerful boost to the growth and development of fuel-efficient vehicles. There are hybrid electric vehicles (HEVs) that emerge from their state of instability and prove to be a promising solution to a major empirical problem posed to mother earth. HEVs provide better fuel economy and low CO_2 emission that satisfies the environmental rules and reduce the effect of rising fuel prices for consumers. HEVs include an internal Combustion engine as well as an electric motor and generator to draw power from fuel and battery respectively to drive the vehicle. Key components of HEVs are an electric motor, generator, battery, and Internal combustion engine. The effectiveness of HEVs depends largely on these components and their structure. This paper will discuss the use of a simple and extensible QSS toolbox that models hybrid vehicle and control systems. The backwards-looking modelling approach was chosen as it is widely used in the sizing of various components of hybrid electric vehicles. In addition, it is easy to model & understand. Also, this paper mainly focuses on the electric drivetrain of an HEV.

Keywords: Fossil fuel, CO_2 emission, Hybrid electric vehicle (HEV), Electric motor, generator, Internal combustion engine, QSS toolbox, Matlab, Matlab Simulink, SOC (State of Charge)

I. INTRODUCTION

A strong and coordinated transportation provides quality to individuals and products. The transportation sector chiefly consists of road, railway, ships, and aviation, wherever road transportation consumes seventy-fifth of the whole energy spent on transportation. The car business plays a big role in the economic process of the planet and therefore affects the whole population. Since vehicles largely run on combustion engines (ICE), the transportation business is responsible for 25%–30% of the whole greenhouse gas emission. ICE works within the method of fuel combustion leading to the assembly of assorted gasses like CO_2, NO_2, NO, and CO that cause environmental degradation within the style of impact (atmospheric phenomenon) and area units to blame for their adverse effect on human health. To beat this, the transportation business is attempting to manufacture vehicles that may run on alternate power sources. Electric vehicles (EVs) were tried as an answer in 1881 wherever the battery alone propelled the vehicle and thus needed a large battery pack. The absence of an Associate in Nursing ICE incapacitated these vehicles with a brief golf range. Hybrid electrical vehicles (HEVs) were conceptualized to bridge the ability of ICE and also the emission-free nature of EVs. HEVs provide higher fuel efficiency over ICE-based vehicles and usually add charge-sustaining (CS) mode wherever the state of charge (SOC) of the battery is maintained throughout the trip. The problem with CS mode is that its charging efficiency depends chiefly on regenerative braking and gas, therefore plug-in HEVs (PHEVs) were conceptualized as a doable answer. Unlike HEVs, PHEVs have the extra facility to be charged outwardly through power shops. Most of the ability during a PHEV comes from an electrical motor (EM) that acts as a primary supply, whereas ICE acts as a backup, because the battery SOC reaches a specific threshold, the PHEV behaves sort of a regular HEV, and also the ICE kicks in and acts as a primary power supply. The PHEVs chiefly add charge depletion (CD) mode wherever SOC is depleted up to strength. PHEVs extend the all-electric range, improve native air quality, and additionally might have grid association capability. Whereas, to manufacture an HEV and test different parameters takes a considerable amount of time, effort, and money. To overcome this problem a virtual model of an HEV is designed and modelled using MATLAB and a simulation is run to get the test results quickly and more efficiently than building a physical model. This paper discusses such modelling of an HEV in Section III using the backward approach with help of the QSS toolbox. Section IV shows the architecture of the HEV model and the results are discussed in further section.

II. RELATED WORK

In traditional ICE vehicles, the energy is conveyed by fossil fuels, whereas in Electric and Hybrid Electric impulse systems the energy conveying medium is either an electrochemical or electrostatic stored energy system. In contrast to ICE-based vehicles, HEV is identified by two or more prime movers and prime sources. The term 'Hybrid' indicates that a vehicle is combined with two prime energy sources i.e an engine and an electric motor. The main incentive is to develop HEVs

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with the prospect to combine the superiority of both vehicles i.e entirely electric vehicles and ICE-based vehicles with no local emissions[1].

The evolution of the basic and expandable Simulink toolset which is used in modelling and controlling HEV. Firstly the design of each and every vehicle subsystem is shown in Simulink then a combination of data and physics-based modelling approaches is applied to continue the model's clarity and precision. These subsystems will finally be combined or arranged to form a series hybrid model. Modelling in Simulink illustrates the modelling process of each subsystem. The provided "Model Parameters" are stored in the "Model Workspace" pane of Simulink's "Model Explorer" tool. The added variables in the model are saved in "MDL". MATLAB and other Simulink models started from the same MATLAB are approachable to "Base Workspace".

In a Series Hybrid Drivetrain, there is coupling between the ICE and the generator, allowing the system to generate electricity for propulsion. The mechanical decoupling with the wheels permits the optimal work of ICE and this results in almost an ideal torque-speed feature, removing the multi-gear transmission. Moreover regenerative In Series- Parallel Hybrid Drivetrain there is an electric machine that integrates the prior mentioned designs. The ICE has the ability to drive directly in parallel, but as there is no operative connection the electric motor becomes the prime mover in series. At lower speeds, the vehicle operates in series mode, whereas at higher speeds there is a decrease in energy in the engine. The Complex Hybrid Drivetrain is similar to the series-parallel design, with the unidirectional flow in the generator and bi-directional flow in the motor. In Spite of this fact, consider it less efficient due to its higher complexity and the demand for an additional power converter to control the flow. Furthermore, there is a discussion on the MATLAB Simulink model including 5 major sub-systems, consisting of the control system, the engine system and electric system, vehicle dynamics, and the power split device. Braking permits the motor to behave as a generator to refill the battery. After all the connections of subsystems depending on the general block diagram of series-parallel design, the final Simulink model is formed.

A well-ordered contemplate of miscellaneous methodologies using a twofold order of electric vehicle use depiction, in view of the time scale and in significant contrast in the illustrating methods. After investigation of interest, it is accepted that action-based displaying (ABM) is the most appealing on the grounds. However, the appropriation of EVs stays languorous because of extended constriction. [4]

III. DESIGN AND METHODOLOGY

For the compilation of this project, the main tool that was used is QSS TB i.e. Quasi-Static Simulation Toolbox. This toolbox gives us optimized and quick results, it also provides estimates for fuel consumption of various powertrain systems. This toolbox is also used in ongoing research projects. The QSS TB makes designing powertrain systems easy and extensible as fuel consumption calculations can be done easily. The QSS TB is not suitable for the dynamic phenomena as it is not based on differential equations. It is more useful in sizing HEV components and their efficiency quickly and easily due to its numerical approach. QSS TB can also be used to calculate a vehicle's harmful emissions[3].

(Quasi-) Static Models: Static and quasi-static models are treated under the same category since both types of models serve similar purposes. The main objectives are to evaluate the performance characteristics, fuel economy, and exhaust emissions of vehicles over predetermined test cycles. The preliminary design and testing of high-level control strategies for HEVs are usually done using quasi-static vehicle models.

Backward-looking models: These models operate based on the assumption that a predefined vehicle speed trace is met by the vehicle. Therefore, the driver behaviour is not modelled in the simulator. Based on the predicted road loads, the tractive power required on the road is carried backwards through the drivetrain until the energy (fuel and electricity) required to meet a given speed trace is computed. These models can be executed faster than forward-looking models, however, they pose major weaknesses as a result of the assumption that the vehicle speed trace is already met. Therefore, it is not possible to simulate events such as full-throttle acceleration in which the vehicle speed trace is not defined a priori and the maximum effort of the vehicle is to be determined.

A hybrid-electric vehicle propulsion system typically consists of a fuel tank, an ICE, one or more electrical energy carriers (e.g., batteries, supercapacitors), electric machines, power converters, transmission, and various driveline linkages. These elements can be combined in various ways to accomplish different objectives. The resulting configurations can be treated under the following general categories:

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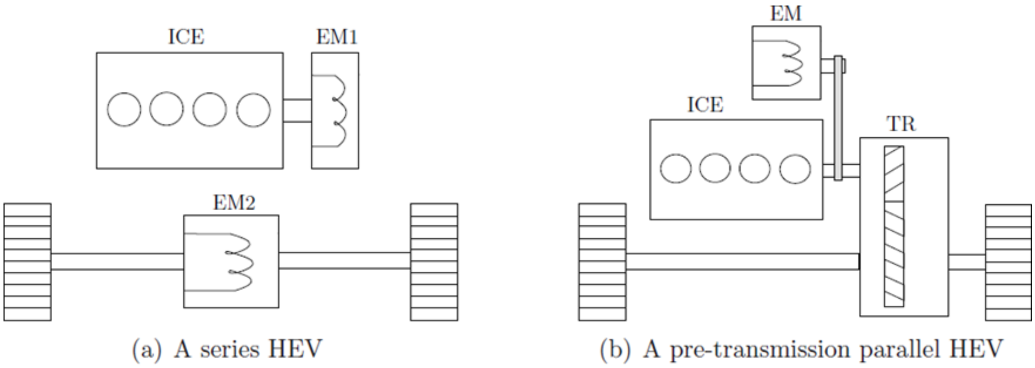

Fig-1 Common hybrid-electric vehicle architectures (TR: transmission, R: ring gear, C: pinion gear carrier, S: sun gear)

IV. THE ARCHITECTURE OF THE EV DRIVETRAIN

The HEV architecture Starts with a driving cycle as it is a quasi-static model and goes into the vehicle, which then connects to the transmission of the electric motor, the torque, and speed requirement is sent to the electric motor and then the electric motor connects with battery to fulfil its energy requirement. This is how the connections are logged with each other.

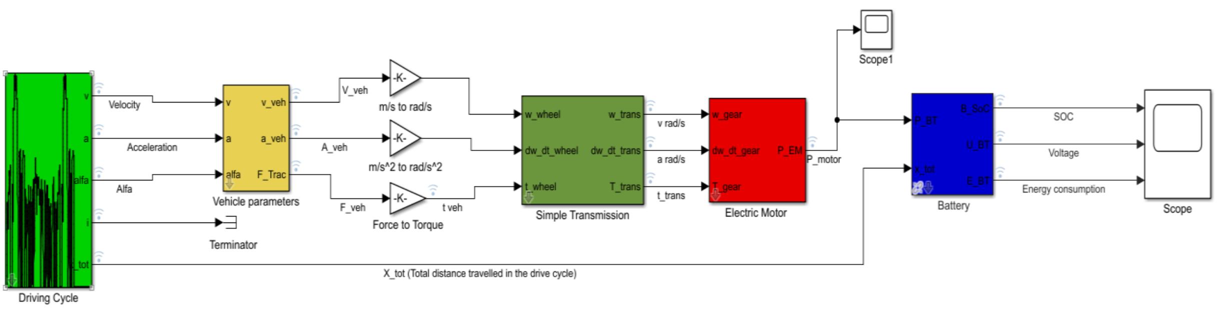

Fig 2 Electric drivetrain of the Hybrid electric vehicle

V. EXPERIMENTAL RESULTS

We have opted for the FTP_75 drive cycle (city drive cycle) for running the tests. The testing started with individual sub-system testing of the battery and once we got the satisfying results we proceeded with the further testing and got several iterations to get the optimum battery power required by the system.

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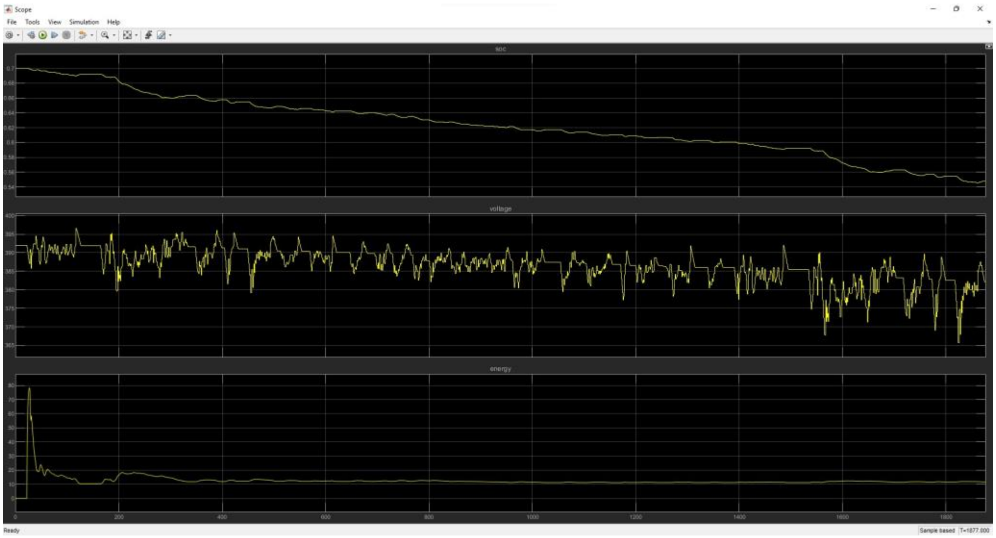

Fig 3: Battery test results

After testing the battery we went ahead and tested the motor block and it gave us the power required from the battery, we also sized the motor according to the torque and speed requirement after several test results. We finalized the motor block for the HEV and went ahead to integrate the system and ran several tests which are shown in Fig 5.

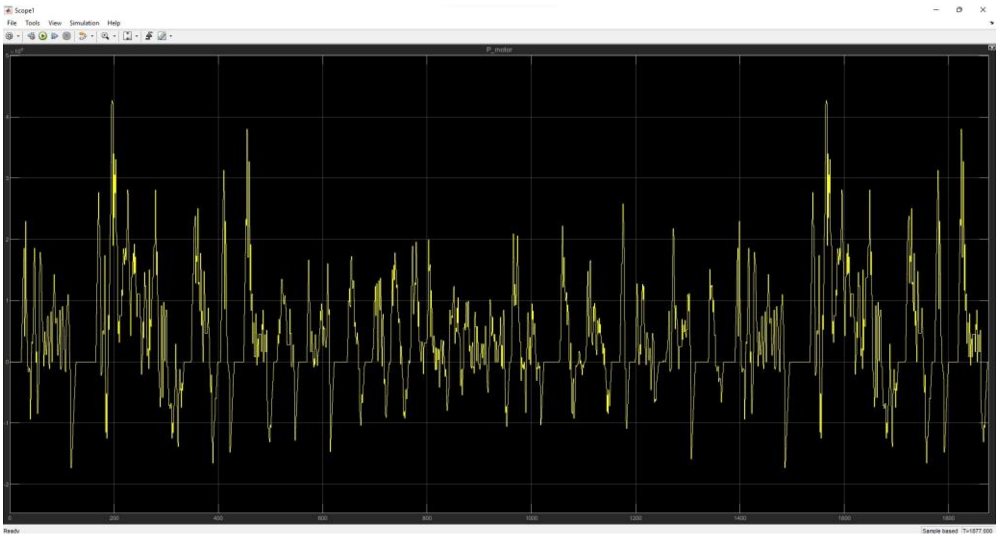

Fig 4: Test Results for motor block

The experimental results clearly show us that the performance of the model is as expected and is able to give us the torque and speed requirement based on the driving cycle provided. It also provides us the information on SOC (State of Charge) at every point and discharge rate and its efficiency. The results also tell us about the peak voltage and current requirements, which can help us to size the motor and battery accordingly with some optimizations to get the best results.

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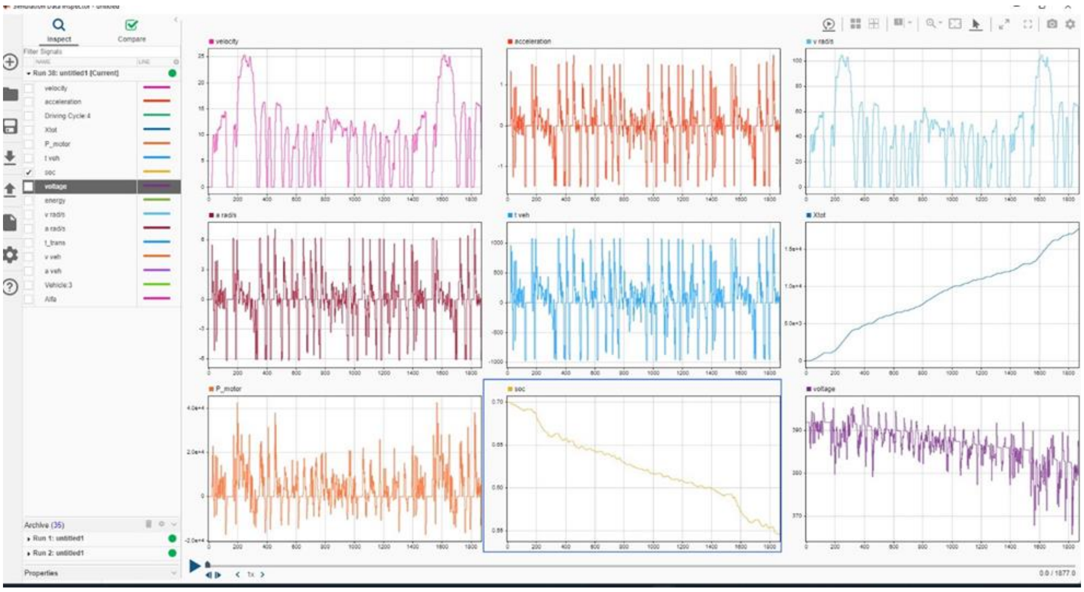

Fig 5: Overall Test results of the EV drivetrain.

VI. CONCLUSION

Simulink was used to model the typical subsystems of an HEV. Physics-based models combined with Data-based models were used to keep the complexity of the overall model at a minimum. This model helps us to size the components of the hybrid-electric vehicle like Battery, EM, Generator, Combustion engine, etc. without investing in manpower, physical vehicle, and testing. This also helps us validate the model with an existing model and improve its efficiency.

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