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Design and Performance Analysis of Hybrid Electric Vehicles using Matlab/Simulink

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ABSTRACT: In this paper introduces an integrated method for the design and performance analysis of hybrid electric vehicles. This method considers a set of parameters that influence the system's performance. Modeling electric vehicles is presented in this project, which takes into account the vehicle dynamics, the drivetrain, and the rotational wheel and load dynamics. It is difficult to select the optimal gains for the hybrid electric vehicle, resulting in unsatisfactory performance. The solution to this problem is to establish a new fuzzy logic controller that sets the rules for a better performance of the system. A fuzzy logic-based gain tuning method for PID controllers is proposed in this project, and it is compared to other control techniques to improve the performance of electric vehicles by improving acceleration, speed, range, controller quality, and response. Simulated results were observed after the model was developed in MATLAB/Simulink.

Keywords: Electric Vehicle, Hybrid Electric Vehicle, Fuzzy System, Power System, Matlab/Simulink

1. INTRODUCTION

The world's oil depletion problem and air pollution have prompted many studies into possible ways of replacing the combustion engine [1]. It is important to announce hybrid and electric vehicles as the future cars, primarily because they do not emit emissions, are quiet and have improved energy efficiency. Around the same time, some issues still need to be resolved, such as limited driving range and long charging time [2]. It is rising steadily, and software is expected to power more than 90 % of automotive systems in the coming years. Because of this, the software effect on electric vehicles will be very strong [3].

The research environment needs to be very practical to have successful results in the testing process. The automotive industry has recently been pushed towards more complex electronic control systems. Around the same time, the mathematical modelling and simulation methods became more sophisticated, and the simulation idea became an actual design method. Simulation is now the main method used before real word research can be carried out [4]. Safety practices and standards are becoming more regulated as the industry adopts standardized product design and test practices. Each manufacturer must offer proof in observance of the new legislation. As a stored source of electrical energy powers electric vehicles, the range of drive is often limited depending on the device's efficiency and the energy source power. Enhancing the electric vehicle control system is one way to increase system performance. Therefore, an effective control system is needed for the robust and energy-efficient operation of the electric vehicle. To this end, this study proposes an adaptive fuzzy technique to control machine operation effectively. Using fuzzy logic helps better resolve uncertainties or unknown variations in plant parameters and the system's robustness [3, 4].

This control method is more robust and allows for various design objectives. Unlike PI controllers, fuzzy controllers

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do not need the process's precise mathematical model; rather, they need the experience and knowledge of the managed process to construct the rule base [5, 6].

Historically used control techniques include PID, Fuzzy logic, and Neuro-Fuzzy controllers. Many research methods have been implemented recently, focusing on advanced electric vehicle control systems. In [7–9], the authors used intelligent fuzzy control to increase the system's efficiency while dealing with the complex operation modes. In [10, 11], different control strategies based on PI methods are used to control the electric vehicle system by mathematical modelling of electric motor and electric vehicle dynamics. These controllers are simple, do not perform well for control systems with changing parameters, and require frequent on-tuning. Tuning is done by manual or hit and trial methods to choose proper gains. The initial gain selection is an important factor in the performance of any controller, careful choice of these gains can lead towards better system response.

Previously, this initial gain selection was made on the control system behaviour information. Still, in the case of a control system with changing parameters, these gains should be adjusted according to the changing system parameters. By calculating the controller gains online, fuzzy logic controls these control systems based on the error signal and its time derivative. These fuzzy logic controllers can be considered non-linear controllers for PIDs. The fuzzy logic works well under changing device parameters, but to make the controller, the initial static gain much more precise must be Properly selected to prevent a suboptimal response. Another fuzzy logic carefully changes the initial static gains operating in parallel with the questionable-tuned PID controller. This additional fuzzy logic controller provides the compensation with the ability to adapt under changing system parameters and make up the system in the gain tuning.

2. ELECTRIC VEHICLE

The electric vehicle [12, 13] integrates the vehicle's body, electric drive, storage tank and energy conservation. It is not only a moving vehicle but a modern form of electrical equipment as well. The electric vehicle is a road vehicle based on modern electric propulsion, consisting of an electric motor, a power converter and a power source, and its distinctive feature properties. Figure 1 displays the electric-vehicle configuration.

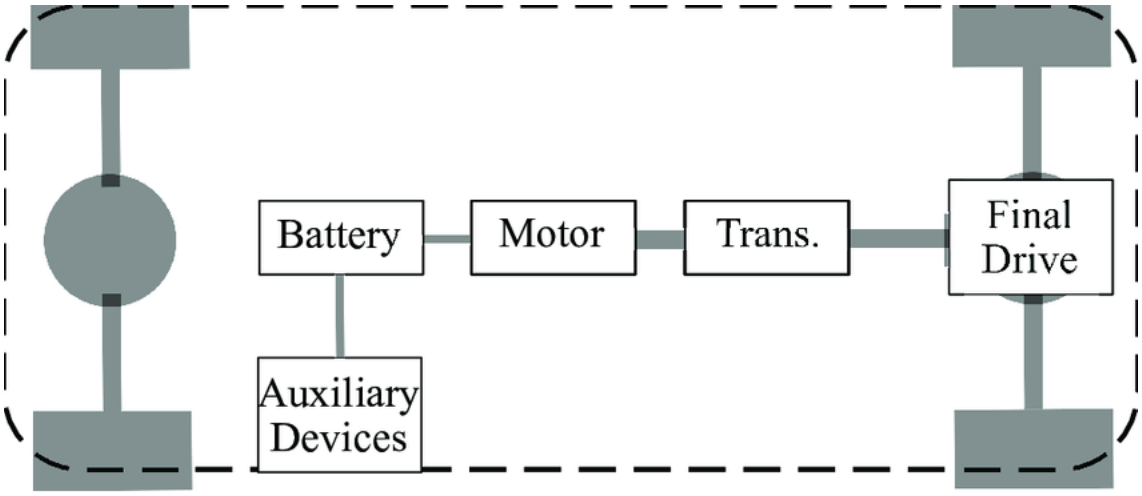

FIGURE 1. **Electric vehicle configuration**

2.1 ELECTRIC MOTORS IN ELECTRIC VEHICLE

Electric vehicle propulsion system [14]. The vehicle is responsible for converting electrical energy into mechanical energy to overcome aerodynamic friction, rolling resistance friction and kinetic resistance. The electronic control can achieve high torque, low speed and constant power in high-speed regions in a modern motor drive. In addition, the configuration of the electric vehicle propulsion may be more versatile, including single or multiple engines, with or without reduction gear, with or without differential gear, and motor axle or plate. The electrical propulsion system consists of a motor drive, a transmitter and an optional wheel transmission unit.

Another of the hybrid motors is a different kind of less motorized permanent magnet brush. The auxiliary dc field winding is integrated into this motor So that the air gap flux is a component of the permanent magnet motor and winding field flux. The flux of air gaps will vary to any degree by changing the field winding excitation current, thus providing maximum efficiency over a broad velocity range. Switched reticence Due to its simplicity and reliability in the configuration of both motor and power converters, the engines offer promising features for electric vehicle applications, a large range of speeds, favourable thermal management, and efficient regeneration braking. They do suffer from ripples of torque and acoustic noise problems, though. In general, for electric vehicles, Slowly substituted dc motor drives by motors, induction motor motors, permanent magnet motor drives with different configurations, and modified reluctance motor drives. These advanced motor drives are specifically designed to meet the particular demands of electric vehicles.

2.2 HYBRID ELECTRIC VEHICLE (HEV)

HEV involves the combination/combining of hybrid vehicles with traditional Vehicles with internal combustion engines. The car, therefore, has two sources of power: an internal combustion engine and an electric motor. It uses both sources to supply the vehicle with the maximum propulsion needed. Depending on the series or parallel link, the link arrangements between Those two sources concentrate the power flow to the wheels. When connecting the Sequential electric motor and ICE, The vehicle is a series of hybrids, and the electric motor provides the mechanical power needed for the wheels. When the electric motor and ICE are linked in tandem, the vehicle is a tandem hybrid, and both the ICE and the electric motor provide the mechanical power needed for the wheels. ICE uses liquid fuel in HEV, and electric motor uses the battery as an energy source. The fuel consumption in the engine can be minimized by using the ICE-compliant electric motor by increasing the torque and rpm. Because of two fuel sources, it offers a choice for greater driving range while overcoming the drawbacks of pure electric vehicles.

The series-parallel model is shown in Figure 2. It combines all series technologies as well as Hybrid Parallel Cars. So this can be done as series and parallel hybrid electric vehicles. Mechanical coupling between the engine and driving wheels of the vehicle is present here. In series-parallel hybrid electric motors, compared to a parallel hybrid, act Less like a pump and less like a motor.

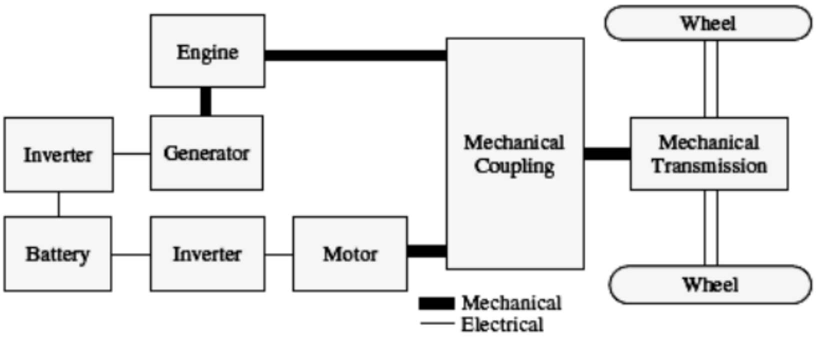

FIGURE 2. **Series-Parallel Hybrid Configuration**

Since this hybrid type operates as a series and parallel hybrid, it is possible to change the fuel output depending on operating conditions. Designing and building are more complex and costly than other hybrid types.

2.3 HEV FUNDAMENTALS

HEVs include both ICE For an electric traction system deriving the vehicle's propulsion. This typically consists of two or more power storage units or power sources in the engine. The ICE is mostly used for steady-state service in HEVs when the electrical system is used. Powertrain is used or relied on for active service. Some of the advantages that HEVs offer are:

- Regenerative braking is a cutting-edge technology not used in conventional vehicles.
- Since ICE will operate with fewer idlers, leading to better fuel economy.
- Simple drivability via electric traction powertrain.
- Condensed emissions.

3. LITERATURE REVIEW

The literature survey was conducted in the following specific categories to recognize the features and configurations of electric vehicles such as a) Hybrid Electric Vehicle, b) Electric Vehicle, c) Fuzzy Logic Controller, d) Electric DC Motor, e) Electric AC Motor, f) Batteries and g) Field Programmable Gate Array.

Author [15] developed a parallel configuration fuzzy logic-based power controller for hybrid vehicles. This controller has been designed to optimize the flow of energy between the main components of the parallel hybrid vehicle (PHV) and the generation and conversion of energy in the individual components. The controller was constructed using efficiency maps of the vehicle components. The power controller layout ensures consistent satisfaction of the driver inputs from the brake and acceleration pedals, at all times adequate battery charging, and maximizing the PHV fuel economy. The simulation results indicate potentially changing using fuzzy logic over other strategies, which optimize only the efficiency of internal combustion engines [16].

Author [17] analyses the Status and future developments in electric vehicle technology, concentrating on the impacts of the rapid growth of electric motors, batteries, microelectronics and new materials. Comparisons have been made on the latest technologies of electric vehicles. It was found that motor drives with advanced power converters, controllers, and batteries are being increasingly embraced. The demand for electric vehicles is fueled by legislation. The author also emphasizes the need for standardization and infrastructure to support the electric vehicle.

The author [18] introduces a detailed analysis of state-of-the-art electric motor drives and power strategies. It was also reported that New high-speed, high-efficiency switching systems, new engine architectures, new converter designs, new control techniques and new high-speed microcontrollers would further improve high-performance motor drives.

Author [19] discussed the essence of automotive control issues, resulting in two Fuzzy logic implementations with a somewhat different focus. The first use of the Fuzzy system was semi-ride system active suspension systems. The simulation results suggested that the fuzzy logic controller achieved better vehicle response to roads and driver inputs with preferable damper switching action and little performance tuning. The second use of fuzzy logic in a hybrid power train was in energy storage. Fuzzy logic's control goal was to sustain the vehicle's reaction while changing how energy was used to reduce the stored energy usage. It was therefore suggested that fuzzy methods give rise to extremely useful results in engineering automobiles [20].

Author [21] presents a survey of the Fuzzy Logic Controller, a general technique for creating a Fuzzy Logic Controller was presented. The author provided, in particular, a debate on fuzzification and defuzzification methods, the derivation of the database and fuzzy control laws, the concept of fuzzy consequences and the study of fuzzy reasoning mechanisms.

Authors [22] built a fuzzy logic controller for an active suspension system with a quarter car. The designed Fuzzy Logic Controller dramatically improved ride performance. They also provided strong damping capabilities for various road inputs, using both body ride and workspace responses to the suspension.

Authors [23] defined current command for highly efficient DC shunt motor torque control, considering the magnetic saturation and armature reaction. The effect of magnetic saturation and armature reaction was considered by defining the electromotive force and torque coefficients as a function of field pressure, armature pressure, and rotating velocity. In the proposed method, the loss of the motor driver system becomes smaller than the loss in the constant field current control, especially in the range of the small torque command. The author also addressed the effect of magnetic saturation and the reaction of the armature on torque control and the reduction of loss of the motor drive system.

[24] Discussed the concept of series feedback controllers and shunt-connected motors based on the linearization feedback technique. It was also stated that these controllers could be built and accurate at all operating points except when unique relationships exist between the currents.

[25] Considered three different non-linear control methods engineering shunt DC motor speeds. The three approaches were linearisation of feedback, linearisation of input-output and regulation of the fuzzy logic. The first two approaches used DC shunt motor mathematical model to reduce the non-linearity & try to establish linear equations. Similar techniques were used in these two methods to construct the controller. The simulation results indicate that the linearisation method of input-output had a very strong response compared to the other one.

The advantage of the input-output linearization approach was to control the direction and speed of the DC shunt motor. In contrast, the feedback linearization approach was used to control speed alone. The authors built the fuzzy logic-based controller to demonstrate how a smart non-linear controller can respond to functions and define applicable rules and fuzzy sets. Finally, the authors conclude by suggesting that smart For those systems may not have access to their mathematical models or have complex non-linear models, control methods such as fuzzy control can be a solution.

[1] Tests show many advantages of adding SR (Switched Reluctance) engines to electric vehicle Drives, High performance and outstanding torque features over a large range of speeds, reliable architecture and fault tolerance and economical mass production capacity. SRDs (switched Reluctance Drive) The design and construction of rotors/stators, the choice of materials, the selection of electronic components and the cost of production were analyzed. The performance features

such as drive power, torque ripple and noise, fault tolerance, efficiency, speed and regeneration torque characteristics was also discussed. Some of these styles and production concerns are often raised in contrast with related problems For electric vehicle drive systems currently in operation.

Finally, it was suggested that the efficiency of SRDs is comparable with other state-of-the-art EV drive technologies [26] described the solutions adopted for the direct wheel drive of an initial, three-wheel electric vehicle (EV) prototype dedicated to urban mobility. A permanent Axial flux magnet motor produces a continuous power of 4.5 KW at 500 rev/min with a total mass of 15Kg at an efficiency of approximately 90 %. The mass production costs of the EV drive system plan are estimated to be compared favourably with those of conventional thermal energy with The same ranking that opens up possibilities for new lightweight, cost-effective EV products intended for commercial use.

4. RESULT & SIMULATION

The electric vehicle used in this research is a form of small-car development suited to urban areas in Indonesia. Figure 3 shows electric vehicles with components such as the induction machine as the primary mover, the inverter as a media link between the DC source and induction machines and the battery as an energy source. The concept is developed using the Simulink / Matlab software.

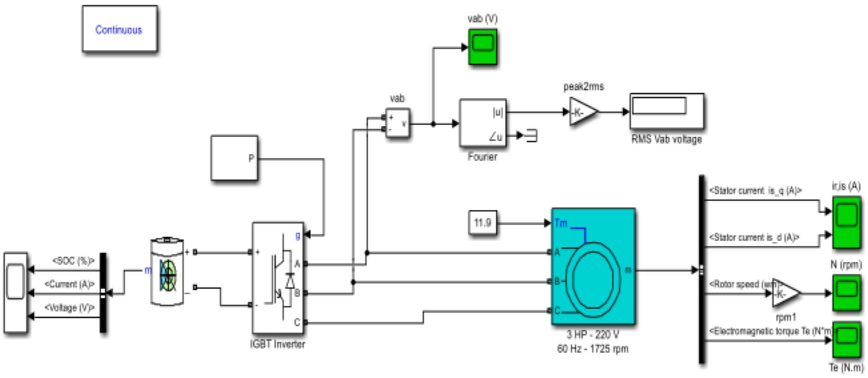

FIGURE 3. **The model of the electric vehicle in this study**

An induction motor is used as the driver has many advantages of being efficient, cheaper, widely used for electric driving at a constant speed, high inertia, and no daily maintenance needed. The induction motor, in coordination with the drive, was designed. Each layout is more versatile than the regular one. As the model can be operated with a non-sinusoidal voltage, the model can still be analyzed even under conditions of a non-symmetrical source.

The battery used as a source of energy is the form of lead-acid batteries, mostly seen on the market and at a fairly low price. That's one major reason why this type of battery should be picked. Furthermore, this battery can start the engine cycle, which needs a relatively high current. The battery's output is a dc voltage/current. At the same time, an electric vehicle with an induction motor uses a power converter to supply the induction motor. The power converter technology used in this model is the PWM Converter.

Unit efficiency is determined by model accuracy. The real-time model is normally compiled and loaded onto a simulator in Matlab / Simulink. The simulation model runs on hardware (single-processor or multiprocessor systems) for the CPU. The Mid-Size Simulator produces I / O signals and tests them through the integrated dSpace I / O boards. The set of functions is complemented by a load and failure simulation [17]. User interface software can monitor a simulator running the simulation model. This device provides direct access to all inputs and outputs of an evaluated EEC. In this test environment, an EEC's inputs and outputs can be seen as an element if an object-oriented scripting language is used to control them automatically. The model that can be easily implemented into a HIL program is used to evaluate the efficiency of the design of the hybrid vehicles. Figure 4 presents an HEV block diagram simulation model for one hybrid vehicle architecture.

The Electronic Control Unit interacts with all major components: The Battery, the DC / DC Converter, the Electric Motor / Generator and the ICE. One can model the structure shown in Figure 2 and the architecture of the HEV system.

- Models of physical components at different fidelity levels are required for HEV growth.
- Modelling the plant and controller in a single setting allows optimization of the device stage.

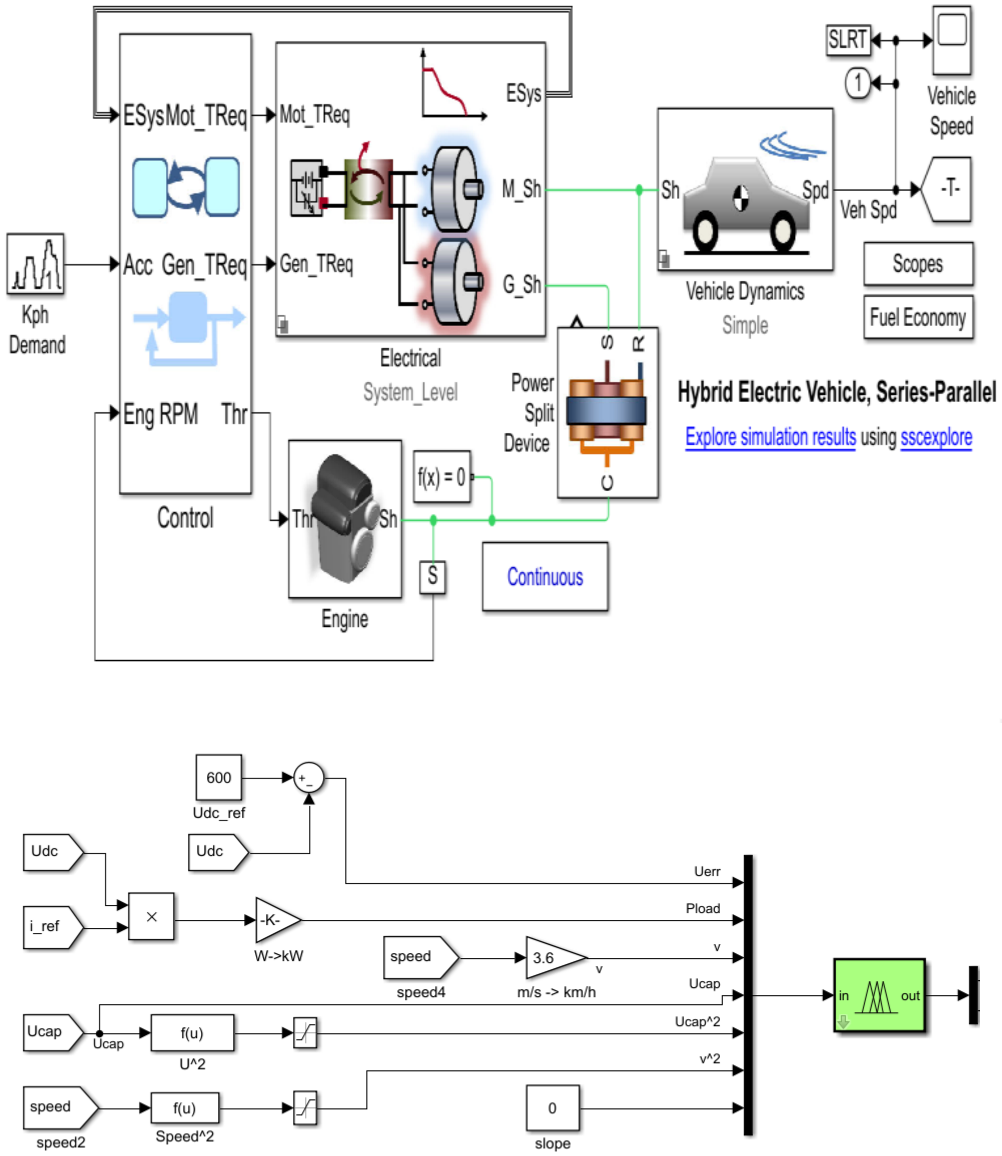

FIGURE 4. **Complete Architecture of Hybrid Electric Vehicle, Series-Parallel with Simple Vehicle Dynamics and below model is Fuzzy Control Model**

- Integration with MATLAB and Simulink makes growth, post-processing and production more effective. The following requirements apply to the functionality of this module.

		ICE
1	Power	57 kW @5000 RPM
2	Min Speed	1000 rpm
3	Max Speed	4500 rpm
4	Torque	115 Nm @ 4200 RPM

5. SIMULATION RESULT

Here the hybrid electric vehicle uses three types of acceleration data and a battery system. The vehicle dynamics are also used in two separate versions, as seen in the above section.

- Result Simulation for Duty Cycle 1, Electrical System Level, Predefined Battery, Simple Vehicle Dynamics Model

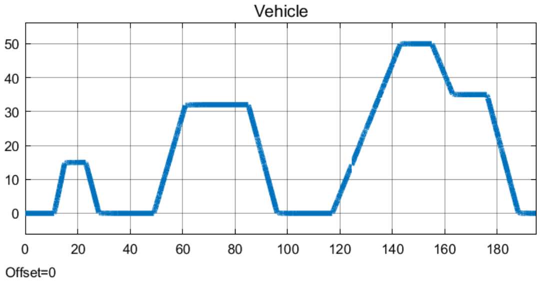

FIGURE 5. **Simulation Analysis for Acceleration of Hybrid Electric Vehicle Model on Duty Cycle1**

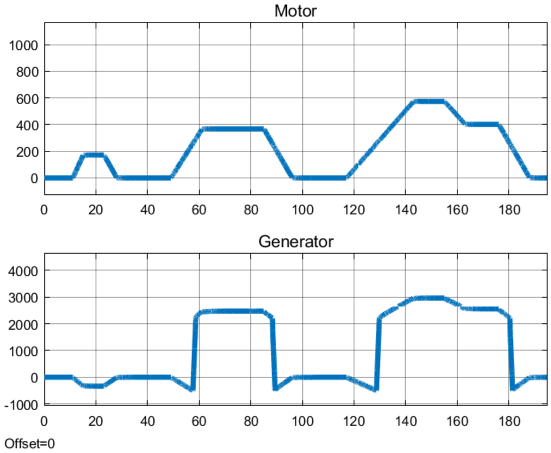

FIGURE 6. **Motor and Generator Speed versus time of Hybrid Electric Vehicle on Duty Cycle1**

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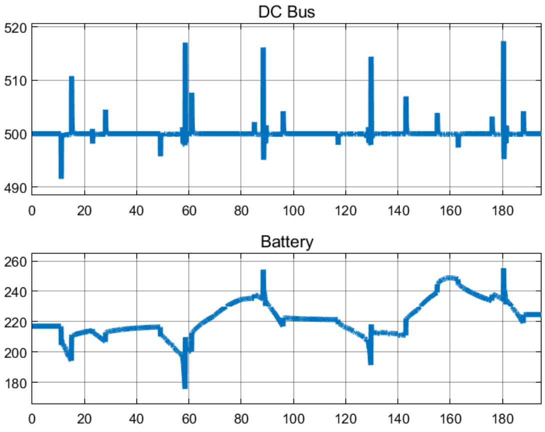


FIGURE 7. **DC Bus and Battery Voltages versus time of Hybrid Electric Vehicle on Duty Cycle1**

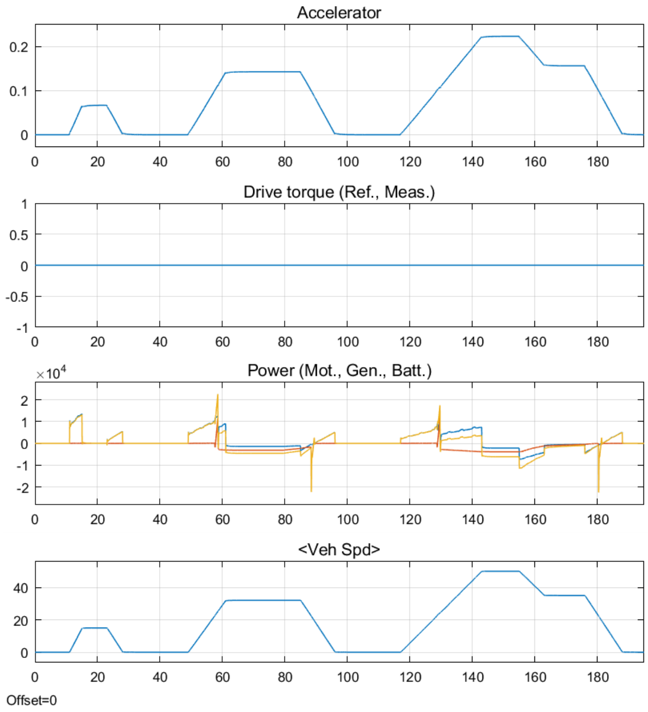


FIGURE 8. **Result Analysis of Vehicle Model of the Hybrid Electric Vehicle on Duty Cycle1**

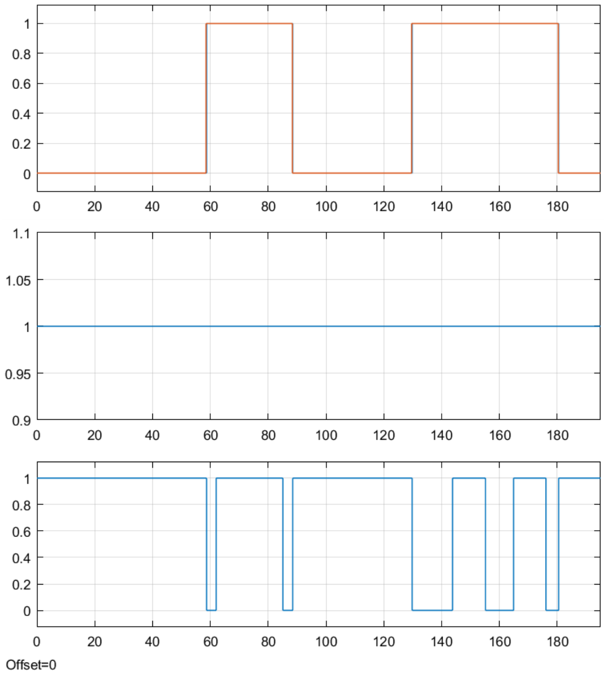


FIGURE 9. Model Control Logic for Hybrid Electric Vehicle on Duty Cycle1

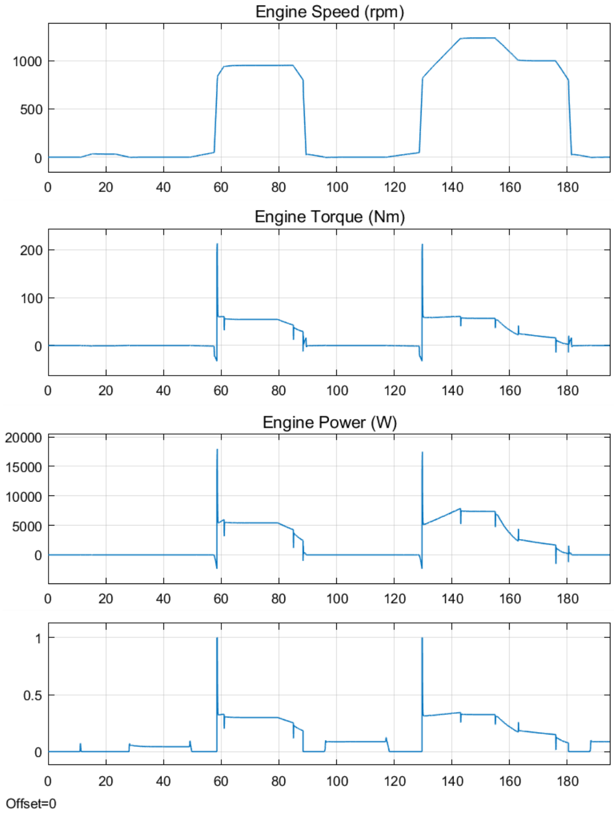
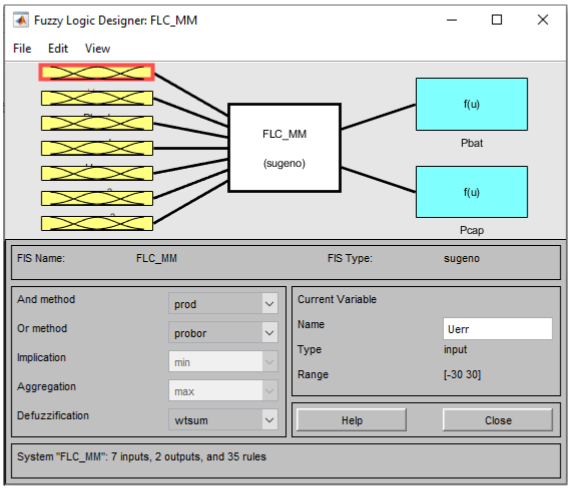


FIGURE 10. Internal Combustion Engine (ICE) performance for Hybrid Electric Vehicle on Duty Cycle1



FIS Name: FLC_MM

FIS Type: sugeno

And method: prod

Or method: probor

Implication: min

Aggregation: max

Defuzzification: wtsum

Current Variable

Name: Uerr

Type: input

Range: [-30 30]

System "FLC_MM": 7 inputs, 2 outputs, and 35 rules

FIGURE 11. **Fuzzy Logic Rule for HEV**

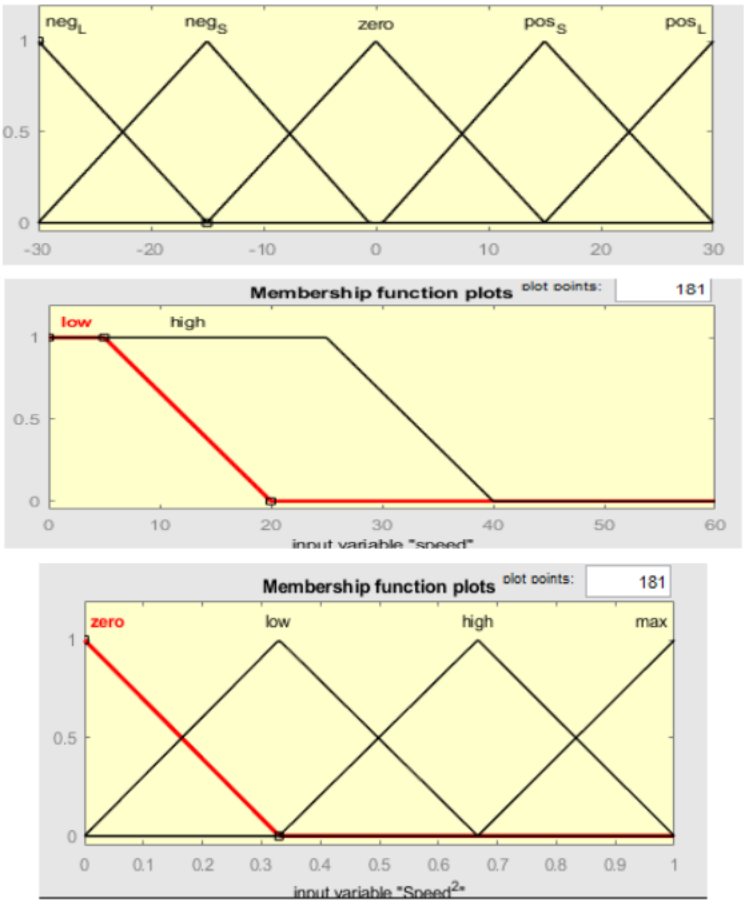


FIGURE 12. **FUZZY LOGIC MEMBERSHIP RULE FOR HEV**

6. CONCLUSION

Modelling the electric vehicle system makes it easy to know how much battery power an electric vehicle requires to operate with certain specifications over a certain distance. This model can be used to estimate the battery life of electric vehicles. The model can also be used to determine the performance of electric vehicles, such as starting or running at a constant speed.

Here we first identified a typical HEV system and presented an overview of the key challenges. We discussed how the complexities of multidomain arise from the dynamic nature of the engine, battery, electrical equipment, controls and vehicle dynamics with different mechanical and electrical components. This complexity and many subsystem parameters make HEV architecture a challenging engineering problem.

We chose Model-Based Design as a feasible approach to solving the problem because of its multiple benefits, including using a single system for managing multidomain complexity, allowing iterative modelling and concept elaboration. Continuous testing and analysis of the requirements reduced mistakes in the design process and production period.

Our first step in the development process was the realization of a whole idea at the level of the HEV method. The subsystem components were average versions, which underwent software development with parallel refinement and design changes. We showed how you can represent the operating modes of the vehicle using state charts. We put it on board into the system- The level model compared the simulation results of the average and detailed models after each component model was developed and noted the impact of model elaboration on the outputs.

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CONFLICTS OF INTEREST

The author declares no conflict of interest.

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