Design And Development of Electric Vehicle

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***Abstract*—The increase in demand of sustainable transportation has led to quick development of Electric Vehicles (EVs). This project assignment is a designing and development of Electric Vehicle (EV) to examine its performance in various driving cycles. Using the MATLAB/Simulink an EV is modelled consisting of all the essential components such as battery, power converter, inverter, electric motor, and vehicle dynamics module. By taking different input conditions as reference such as FTP-75, Wide Open Throttle (WOT), and custom signals generated through Signal Builder this system is analyzed on its performance towards these conditions. Required important parameters like State of Charge (SOC), vehicle speed, power consumption, and efficiency are verified. The findings of our project demonstrate that driving conditions are important factors that influence battery utilization and the general system functionality. Our developed model offers a highly convenient platform to assess the behavior of behavior of EVs and enhance the energy management strategies.**

***Index Terms*—Electric Vehicle (EV), MATLAB/Simulink, Battery State of Charge (SOC), FTP- 75 Driving Cycle, Wide Open Throttle**

I. INTRODUCTION

The booming industrialization and transportation have led to the rise of the energy demand particularly in the automotive industry. Traditional cars with Internal Combustion Engines (ICE) rely on fossil fuels, which cause environmental problems, including air pollution, greenhouse gases, and global warming. Moreover, fuel depletion and price fluctuations of fuel cause concerns over sustainability. EVSs have come up as a viable and environmentally friendly alternative. They use rechargeable batteries to drive electric motors, which have some benefits, which include: high efficiency, low emission, reduced noise and reduced maintenance. Sophisticated battery, power electronics and control systems have additionally enhanced the performance of EVs. Such attributes as regenerative braking make it more efficient, restoring energy during braking.

Nevertheless, EV performance is affected by the driving conditions, the vehicle load, and the characteristics of the road. To model this, standardized driving cycles are employed to model real world conditions. Physical prototypes are not required to model and analyze EV systems in detail with simulation tools, such as MATLAB Simulink. The project is aimed at designing and simulating an EV model to test its performance under various driving conditions, comparing the results of different parameters, including energy consumption, battery State of Charge (SOC), and efficiency.

II. ELECTRIC VEHICLE SYSTEM DESIGN

ELECTRIC VEHICLE ARCHITECTURE

Electric Vehicle (EV) system is a system that is built by combining electrical, mechanical, and control subsystems to transform stored electrical energy into mechanical motion. The Flexible components encompass the battery pack, electric motor, power electronics controller, DC -DC converter, inverter, charging system, controller unit, and vehicle dynamics module. All the parts are important towards providing effective vehicle performance.

BATTERY PACK:

The EV uses a battery pack as its main energy source; this provides DC power to the system. The Li-ion batteries are widely used because of their high energy density, lightness, long life, quick charging, minimal self-discharge, and high efficiency. The battery has a considerable influence on the driving range and the performance.

ELECTRIC MOTOR:
A BLDC or PMSM type of electric motor transforms electrical energy into mechanical force. It employed in this project because it is highly efficient, small in size, low in noise and responsive. It can also be carefully controlled with electronic systems.

POWER ELECTRONICS CONTROLLER:
Power electronics controller controls the electrical energy flowing between the motor and battery. It serves as a connector and it employs devices such as inverters to propel the motor. It also regulates the speed of the motor and torque by adjusting the voltage and current.

DC-DC CONVERTER:
The DC-DC converter modulates the voltages in the system. It steps down battery voltage to power low-voltage devices and ensures a stable power supply, improving overall efficiency.

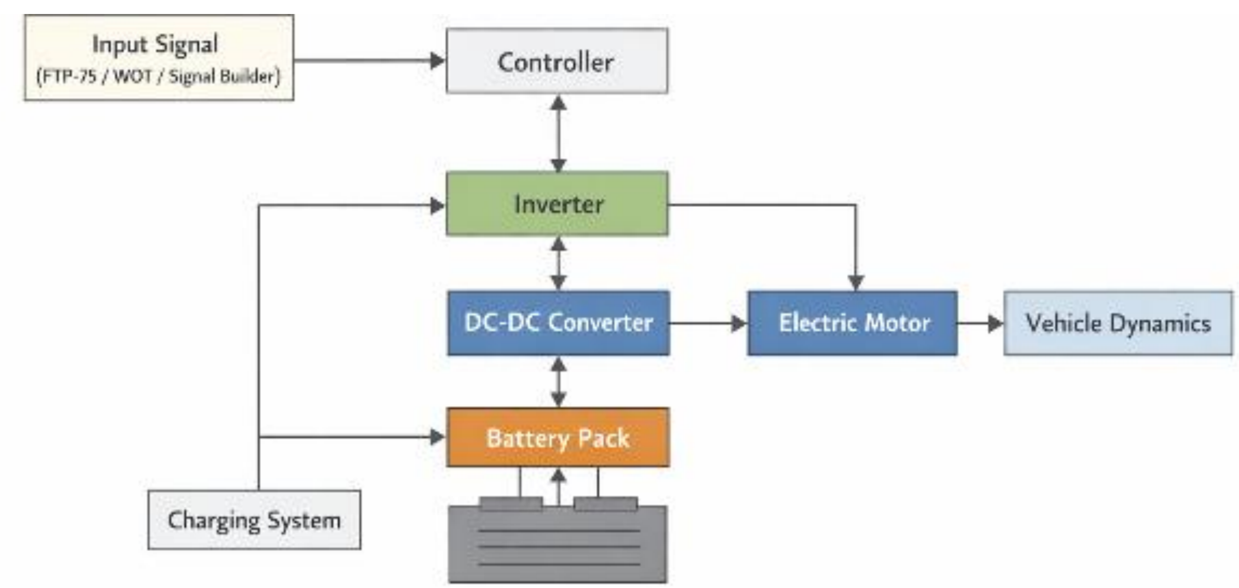
INVERTER:
The inverter changes the DC power supplied by the battery to AC power needed by the motor. By changing the output voltage and frequency, it regulates the speed and torque of the motor.

CHARGING SYSTEM:
The battery can be recharged by using the charging system to recharge the battery by using an external source. It consists of such parts as the charger and charging port, which would guarantee safe and efficient transfer of energy.

CONTROLLER UNIT:
The controller unit is the brain of the system. It processes driver inputs, regulates motor speed and torque, regulates power flow, and monitors such parameters as voltage, current and temperature. It transmits control signals to the power electronics and the motor. Control unit involve Arduino board, LCD display, and switch.

- Arduino Board: A microcontroller that processes inputs, drives components, and performs programmed functions.
- LCD Display: Displays system information such as readings and status.
- Switch: Control the system ON/ OFF, and the choice of various driving modes or input signals.

VEHICLE DYNAMICS MODULE:
The vehicle dynamics module is a physical behavior of the vehicle. It takes into account such forces as rolling resistance, braking, and road conditions to calculate vehicle motion.



III. MATHEMATICAL MODELING OF THE SYSTEM

The performance of the Electric Vehicle (EV) is analyzed with the help of mathematical modeling, which describes the forces, acting on the vehicle, power needed, and battery behavior.

TRACTIVE FORCE ANALYSIS:
The summation of all the forces acting on the vehicle is the total tractive force
(F_t): $F_t = F_r + F_d + F_g + F_a + F_i$
Where: F_r: Rolling resistance, F_d: Aerodynamic drag, F_g: Gradient force, F_a: Acceleration force, F_i: Inertial force

ROLLING RESISTANCE:
Force due to tire-road interaction.
$F_r = m \cdot g \cdot Cr$
Where: m = mass, g = gravity, Cr = rolling resistance coefficient.

AERODYNAMIC DRAG:
Force due to air resistance.
$F_d = 0.5 \cdot \rho \cdot Cd \cdot A \cdot v^2$
Where: ρ is air density, Cd is the drag coefficient, A is the frontal area, and V is the velocity.

GRADIENT FORCE:
Force caused by slope of road.
$F_g = m \cdot g \cdot \sin(\theta)$
Where: θ = road angle

ACCELERATION FORCE:
Force required for acceleration.
$F_a = \lambda \cdot m \cdot dv/dt$
Where: λ = rotational inertia constant

INERTIAL FORCE:
Force due to acceleration.
$F_i = m \cdot a$

POWER REQUIREMENT:
Power needed to propel the car: $P = F_t \cdot v$ The more force and speed, the more the power.

BATTERY MODELING: Coulomb counting
State of Charge (SOC): $SOC = SOC_0 - (1/Q) \int i(t)\, dt$
Where: Q = battery capacity, i(t) = current. The method can be used to estimate battery energy consumption.

IV. DRIVING CYCLES USED

In order to test the work of the Electric Vehicle (EV), it is necessary to test it in real-world conditions. In simulations, predefined driving cycles and input signals are used because it is not always feasible to test this practically. The inputs can be used to study the vehicle behavior at various speeds, acceleration, and loads. In this project, three input conditions are used: FTP- 75 driving cycle, Wide Open Throttle (WOT), and Signal Builder inputs.

FTP- 75 DRIVING CYCLE:
FTP- 75 is a symbol of city traffic conditions, where there is a high number of stops and starts. It has various stages, including cold start, transient start, and hot start, which mimics a real-life traffic scenario. Involves a lot of acceleration, deceleration and idle time. Top outcomes in increased use of energy. Some energy is recaptured with the help of regenerative braking.

- Applications: Evaluating urban performance Analyzing battery discharge Learning about energy use and efficiency.

WIDE OPEN THROTTLE (WOT): WOT is the state in which the accelerator is pushed to the max and requires the system to give its best. Gives optimal power and fast acceleration. Places the battery and motor with heavy load. Performance limit analysis.

- Applications: To find maximum power and torque.

SIGNAL BUILDER INPUT: Signal Builder is employed to create custom input signals which are used in simulation. Enables development of user-defined speed or throttle profiles. Applicable to controlled and specific test conditions.

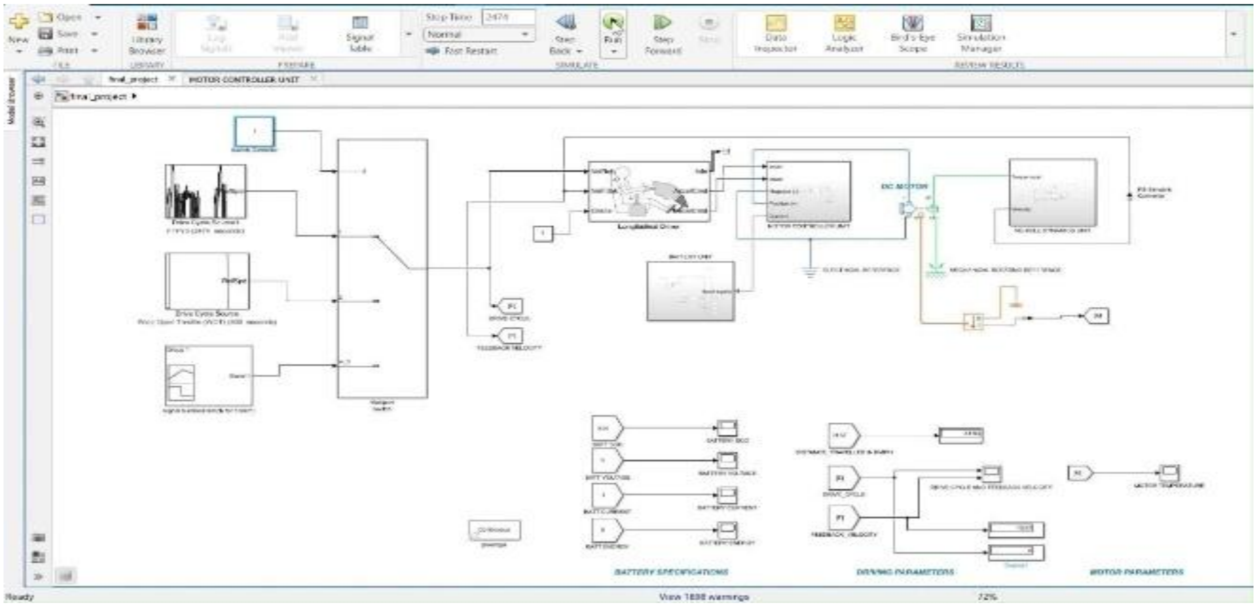
- Applications: Gradual or step speed changes. Constant speed testing Custom driving scenarios.

COMPARISON OF INPUTS:

- FTP- 75: Real-life urban driving and energy use.
- WOT: Tests system limits and performance.
- Signal Builder: Allows custom testing.

V. SIMULATION MODELLING

MATLAB/SIMULINK BLOCK EXPLANATION



The EV model is created using interconnected blocks of MATLAB Simulink that depict various subsystems.

Drive Cycle Source:
This provides the input signal like FTP-75, WOT, Signal Builder to provide the various driving conditions.

Switch Controller:
Selects the necessary input signal and transmits it as reference speed.

Longitudinal Driver:
Comparisons reference and actual speed to produce acceleration and braking signals.

Motor Controller:
Regulates the voltage and current of the motor. Battery Unit: Provides power and gauges SOC, voltage, current and energy consumption.

DC Motor:
Transduces electric energy into mechanical force.

Vehicle Dynamics:
Model of vehicle movement depending on the torque, mass, and road conditions.

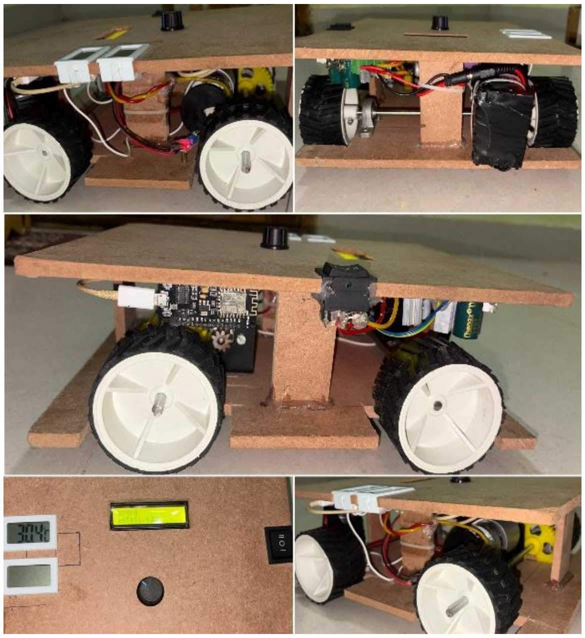
Output Displays:
Displays SOC, voltage, current, speed, distance and temperature.

SIMULATION METHODOLOGY

The simulation is carried out step-by-step to analyze EV performance under different conditions:

- Model Development: All EV subsystems like battery, motor, controller, and vehicle dynamics are modeled and networked in Simulink.
- Input Selection: The switch block is used to select driving inputs (FTP-75, WOT, or custom signals).
- Speed Control: The longitudinal driver compares actual and reference speed and produces control signals.
- Motor Operation: The motor controller modulates both voltage and current to provide the desired speed and torque.
- Vehicle Response: Motion is computed as the product of torque and external forces on the vehicle, and this is computed by the vehicle dynamics block.
- Performance Measurement: SOC, energy consumption, speed tracking, and efficiency are some of the key parameters monitored.
- Analysis: Various driving conditions are tested to compare results to system performance.

VI. RESULTS AND DISCUSSION



This EV model is simulated and tested in FTP-75 and WOT conditions in MATLAB/Simulink. The most important are speed, SOC, power, current and efficiency.

Speed Tracking: The EV closely follows the reference speed.

- FTP-75: Tracking is good with slight deviations during acceleration/deceleration.
- WOT: Minimal lag because of high acceleration requirement.
- Robust and consistent performance of control

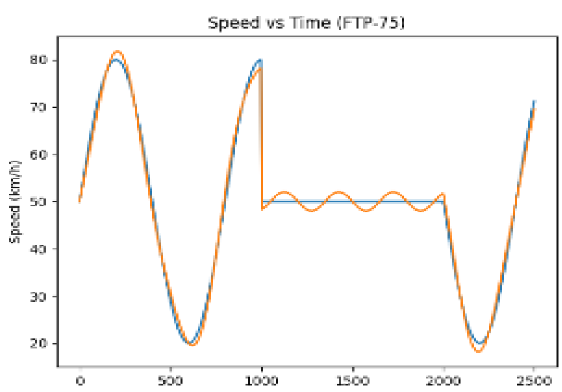


Fig 1. vehicle speed tracking under FTP- 75 drive cycle

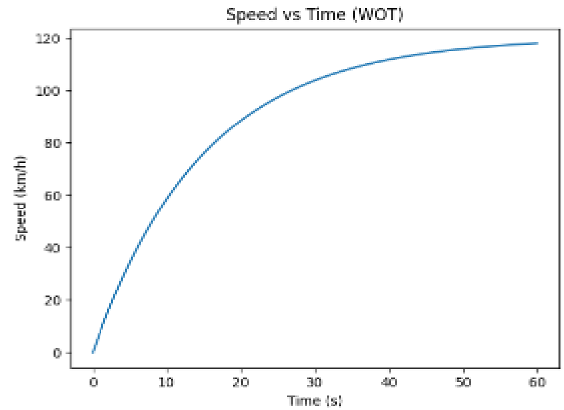


Fig .2 Vehicle speed tracking under WOT drive cycle

Battery SOC: SOC is dependent on driving conditions

- FTP-75: Gradual decrease
- WOT: Quick reduction in power consumption.
- Driving pattern affects battery usage.

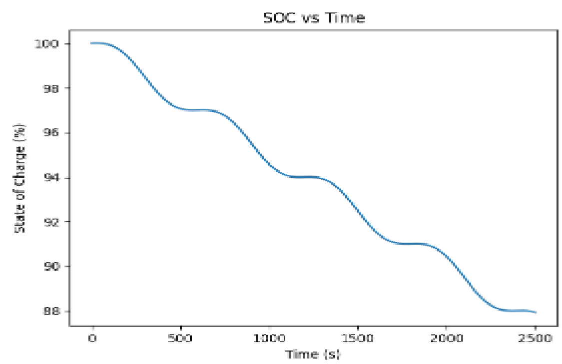


Fig 3 Battery SOC variation under FTP- 75 drive cycle

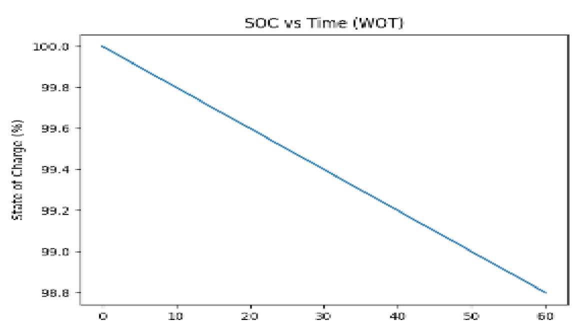


Fig 4 Battery SOC variation under WOT drive cycle

Power Consumption

- WOT: Continuous, maximum power demand.
- FTP-75: Regenerative braking that produces fluctuating power.

- Aggressive driving increases energy consumption.

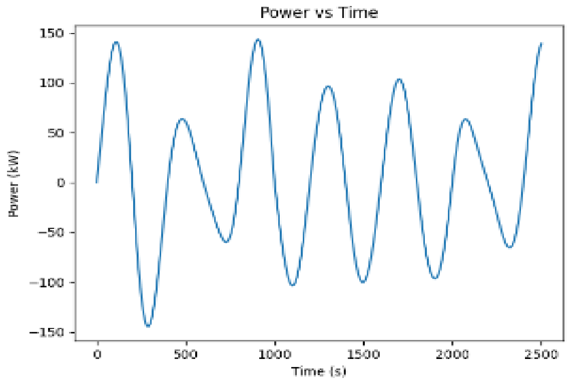


Fig 5 Power demand during drive cycle

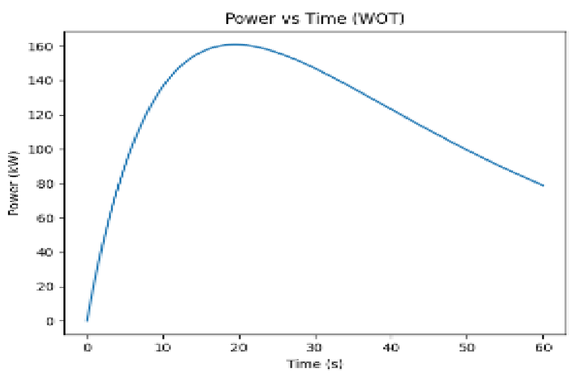


Fig 6 Power variation under WOT drive cycle

Battery Current

- WOT: Large continuous current.
- FTP-75: Varying current with regeneration
- Battery design and safety.

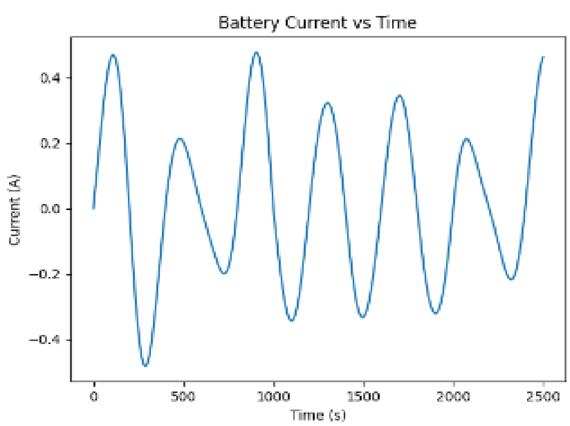


Fig 7 Battery current profile under FTP- 75 driving cycle

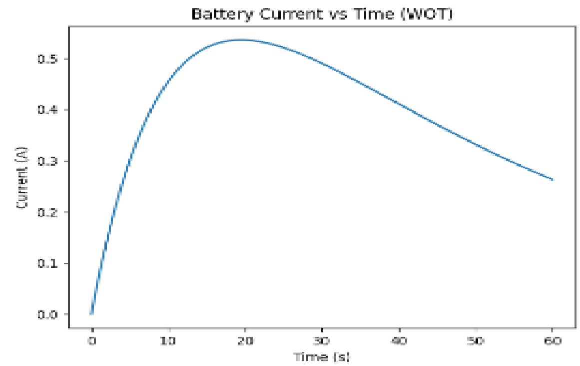


Fig 8 Battery current under WOT drive cycle

Motor Torque variation

- FTP-75: Torque changes with time, high acceleration and negative braking (regeneration).
- WOT: Large initial torque to accelerate high, and then drops off as speed increases.

Torque is a factor of the condition of driving and the load demand.

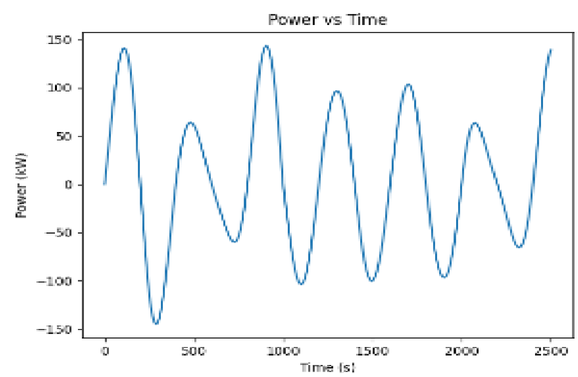


Fig 9 Motor torque variation with time under FTP- 75 driving cycle

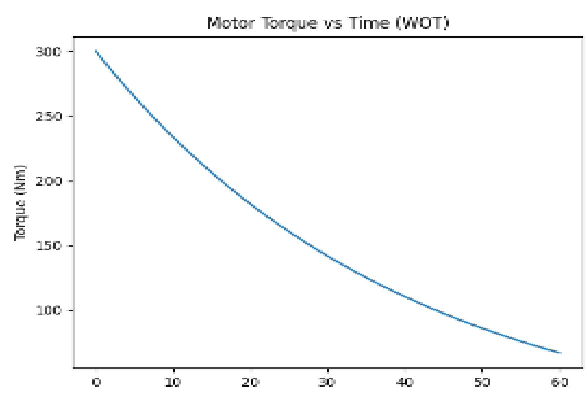


Fig 10 Motor torque variation under WOT drive cycle

Efficiency
- Increases at constant speeds.
- Lower during acceleration Enhanced with regenerative braking.
- FTP-75 is more effective than WOT.

VII. DISCUSSION

- FTP-75: Moderate, realistic, efficient energy consumption.
- WOT: Large power consumption, fast SOC drop.
- Efficient driving is smooth, and aggressive driving is short of battery life.
- It must have proper design of battery, motor and control.

VIII. CONCLUSION

This project designed and simulated the model of an Electric Vehicle (EV) in the FTP-75 and WOT conditions of MATLAB Simulink. The findings indicate good speed tracking with slight deviations, and motor torque and power changes depending on driving conditions. The battery analysis shows a decrease in SOC when the current increases at acceleration and an increase in SOC during braking. In general, the driving conditions are influential factors that can greatly influence energy consumption and efficiency of the system and the model is efficient in analyzing the performance of EVs.

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