E-Truck Powertrain and Braking

PACCAR

PROJECT BACKGROUND

The E-Truck challenge is a 4-year challenge to convert a diesel truck into a Class-7 EV. As the powertrain and braking team, it was our responsibility to create a simulation of the powertrain and braking components, evaluate and validate the truck CAD for implementation of new powertrain components, and work with the HV architecture of the truck.

E-TRUCK DIGITAL TWIN

Building the Simulink Model

A digital twin of the truck allows the team to test different driving conditions through simulation and obtain motor and battery behavior. The model was built using Simulink and takes a velocity profile as the input. The profile is transformed into accelerator and braking commands, processed into torque commands and then outputs the vehicle speed. There is also a battery subsystem that limits the motors power draw based on SoC. Some of the biggest challenges included determining signal processing and hierarchy and fine tuning logic gates and driver braking behavior to obtain an accurate model.

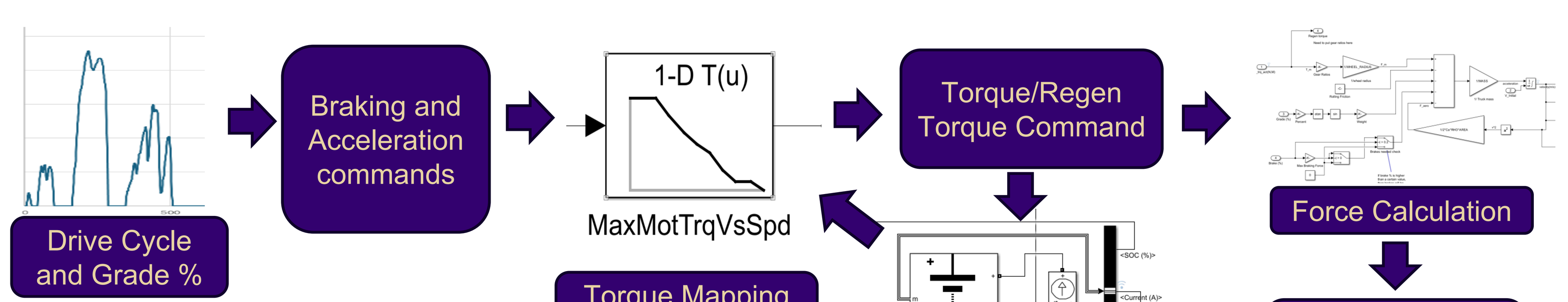

Figure 1. Flow and transformation of signals in the Simulink Digital Twin.

RESULTS

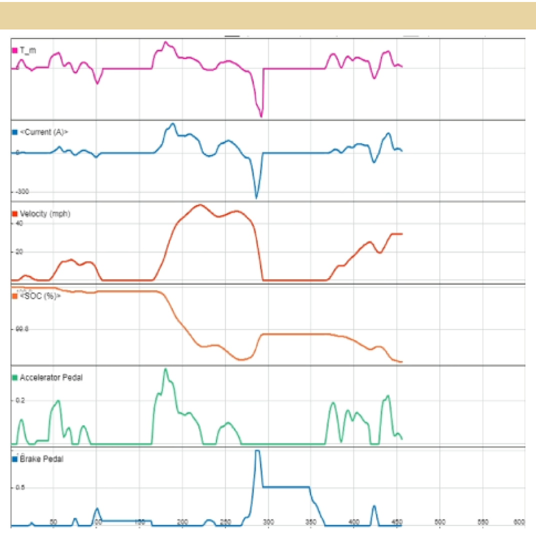

Figure 2. An accumulation of the different signals from our powertrain simulation. From top to bottom: torque, battery current, velocity, SOC, accelerator pedal, brake pedal.

The output velocity profile is used as validation that the model ran correctly. Then, we can extract signals from the model such as:

1. Accelerator and braking %
2. Motor torque, RPM, and power draw
3. Vehicle speed, acceleration, and distance traveled
4. Battery voltage, regen current, SOC

Braking System and Requirements

Regen braking is modelled in the Digital Twin and represents the motor behavior. The old brakes will be reused since we are choosing an e-motor, and a Bendix E-compressor will regulate the air pressure. Air braking will only be applied if regen does not meet required deceleration or if brake % passes a certain threshold.

Table 1. List of Brake Requirements

Deceleration from 20-0	-14 mph
Braking force	14355 lbs
Brake release time	0.55 seconds
Brake response time	0.45 seconds

HV ARCHITECTURE & CONTACTOR BOARD

DESIGN

A high-voltage contactor box has been designed to safely manage power distribution between the battery, inverter, and auxiliary systems. This includes integrating an insulation monitoring device (IMD), Precharge, Discharge, Current/Voltage Monitoring and Contactor Control. In addition, busbar sizing has been performed to ensure adequate current-carrying capacity and minimize resistive losses. We have also started component selection to ensure proper voltage/current ratings.

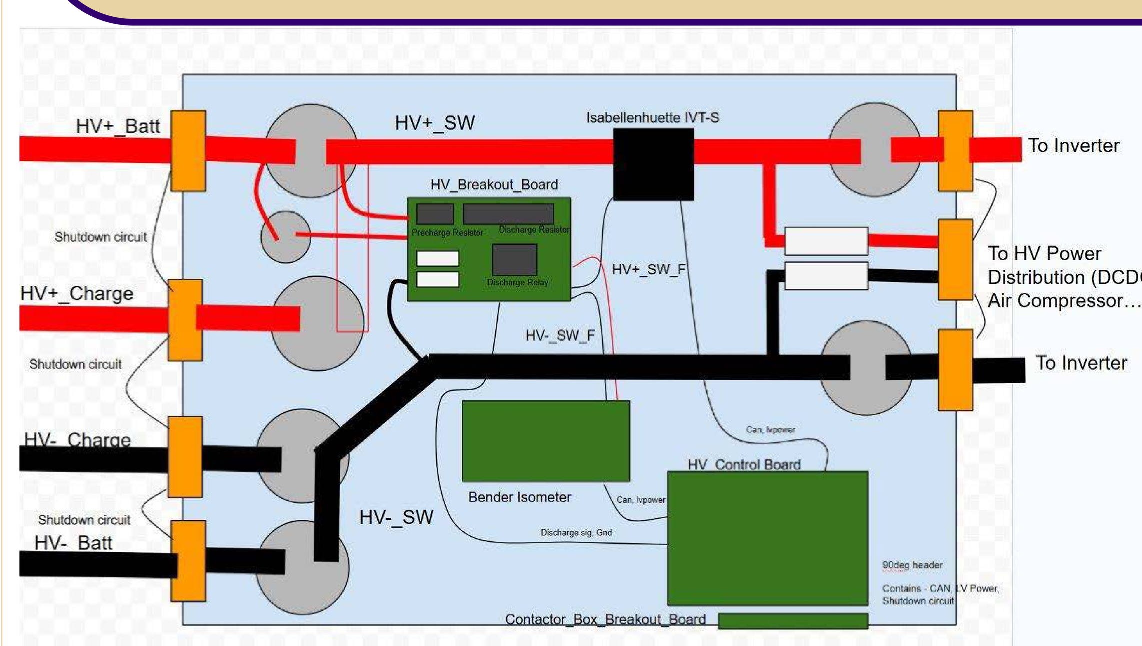

Figure 3. High-Voltage Contactor Box Layout

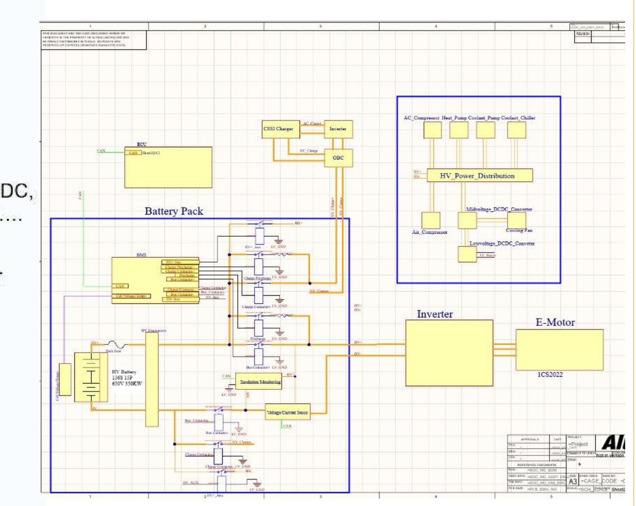

Figure 4. High-Voltage System Schematic

CAN/ECU SIGNAL PROCESSING

DESIGN

The Controller Area Network (CAN) allows different components to communicate, while the Electronic Control Unit (ECU) processes and responds to the signals. Key powertrain and braking data were identified and mapped to CAN message in the Simulink model, with attention to byte order (big and little endian formats) and scaling factors to match J1939 standards. The process includes simulation validation and preparation for CANalyzer testing of verify in-vehicle integration.

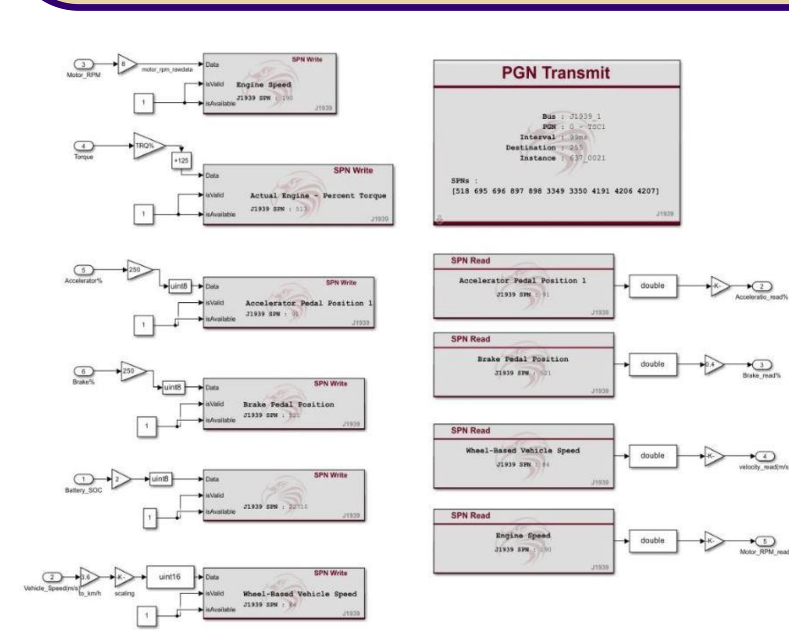

Figure 5. Simulink CAN implementation showing J1939 SPN blocks for key signals with scaling methods.

RESULTS

- Signals are mapped to J1939 SPNs using standard PGNs and data formats
- Scaling factors are applied to match required resolution
- Data Types are selected to align with SPN definitions
- Byte order is configured per J1939 specifications

MOTOR AND BATTERY HARMONICS

ANSYS Simulation

A harmonic analysis was carried out for multiple configurations of E-motor and Battery mounts. These simulations account for tire and suspension behavior, as well as the truck payload. By representing interaction with the road as a sinusoidally varying force, resonant frequencies can be investigated and avoided in the final design. An example simulation is pictured below.

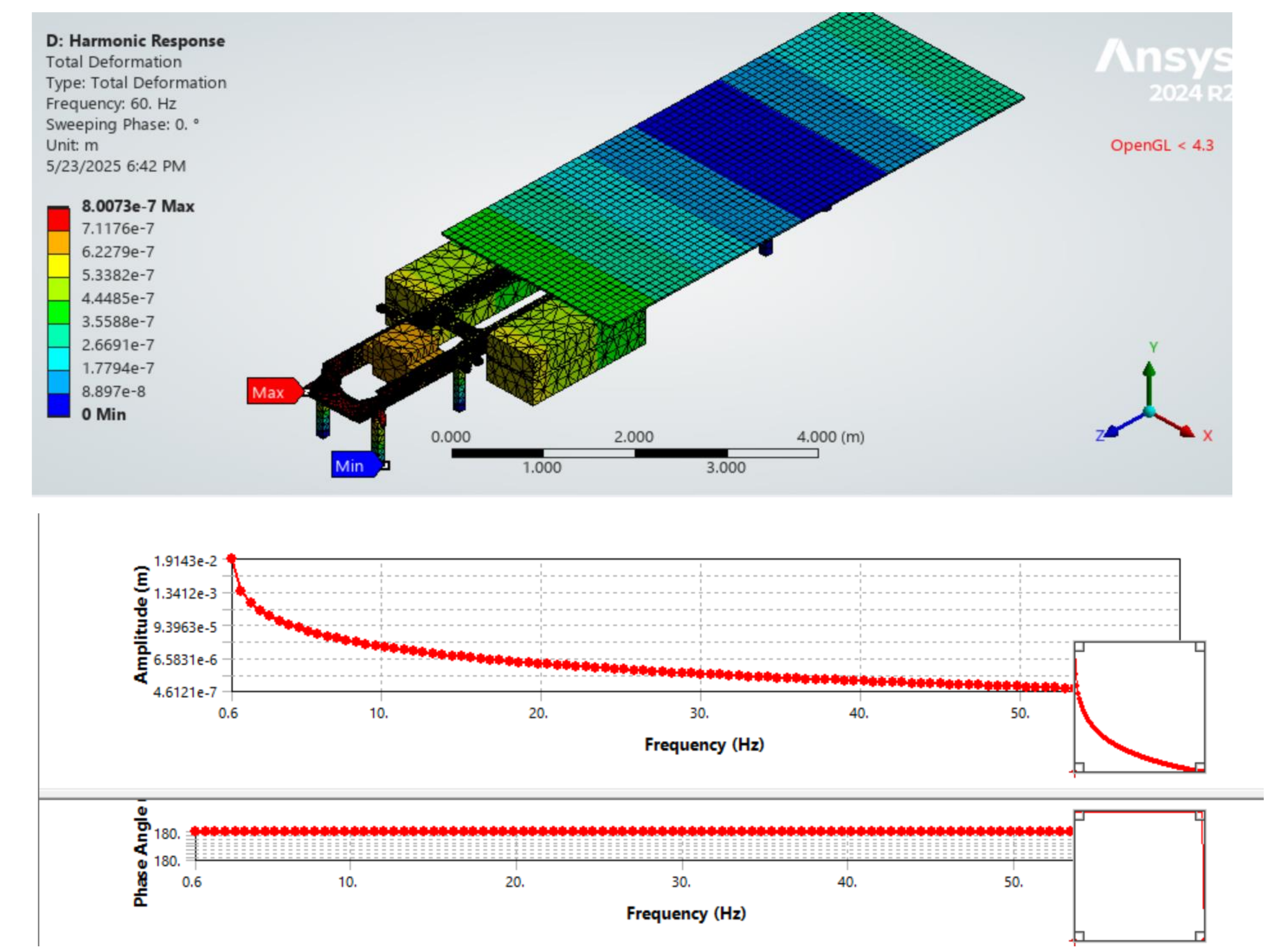

Figure 6. Harmonic total deformation and frequency response for Configuration 1 of the truck.

Conclusion and Next Steps

The Simulink and FEA models are expected to facilitate the finalization of design choices regarding performance, component mounting positions and controls systems. According to the tests, none of the configurations will resonate with the frequencies imparted by the road. Configuration 1 experiences the least amount of deformation. Future projects include HV cable routing, HIL test bench, and digital twin tuning.

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Mechanical Engineering Capstone Exposition

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