MATLAB EXPO

2024.06.11 | 그랜드 인터컨티넨탈 서울 파르나스

Prediction of Work and Driving Performance of Electric Excavator using System Simulation

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MathWorks

Contents

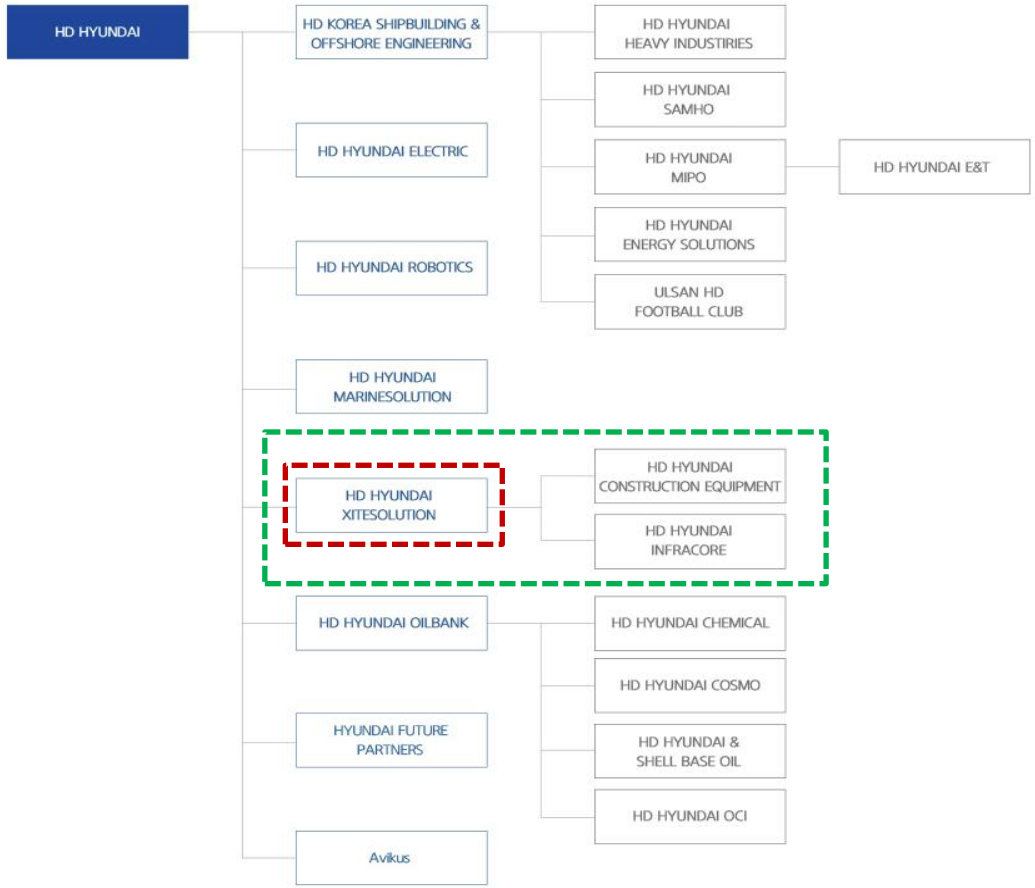
- Introduction to Organization and Business
- Project Overview (Goals, Challenges, and MathWorks Solutions)
- Modeling Electric Excavator for Power Performance of using System Simulation
- Achievements and Outlook
- Current Works and Next Plan

*VPD: Virtual Product Development

Introduction to Organization and Business

HD HYUNDAI XITESOLUTION HD HYUNDAI INFRACORE HD HYUNDAI CONSTRUCTION EQUIPMENT

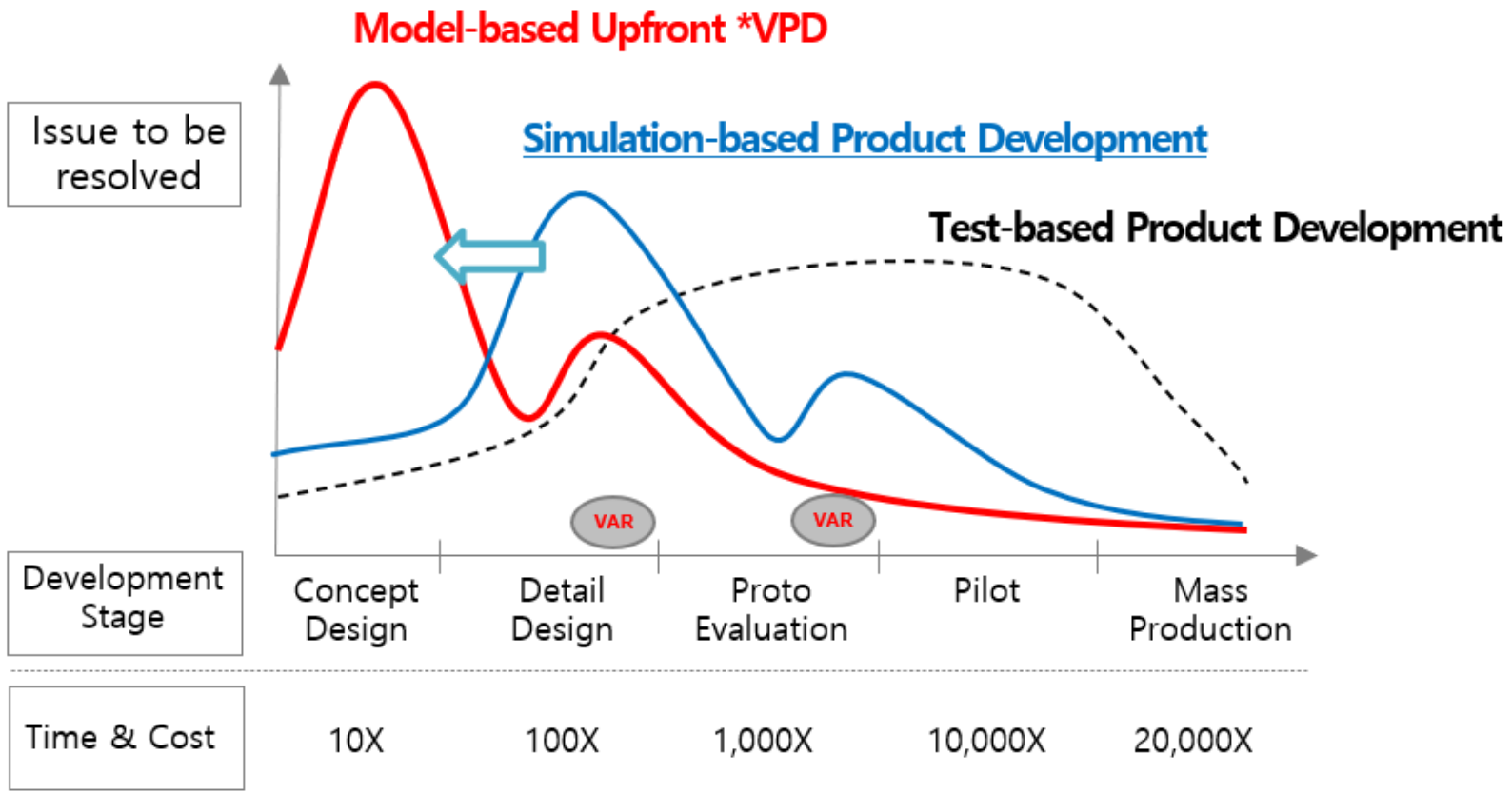
Building a Better Future with the Most Innovative Industrial Solutions



- **Growing into a global top-tier company that represents Korea's construction machinery industry.**
- **HD Hyundai XiteSolution is intermediate holding company in the construction machinery sector, with *HDI & *HCE as subsidiaries.**
- **Our own business area: *MCVs, Transmissions, Cylinders, and other hydraulic parts.**
- **Providing optimized solutions to HDI & HCE for synergy in development, sales, purchasing, and international business.**
- **Creating blueprint for the future of the construction machinery industry in Korea by growing together with our partners.**

*HDI: Hyundai Infracore, HCE: Hyundai Construction Equipment, MCV: Main Control Valve

Model-based system simulation is very effective for achieving design goals through optimization while considering multi-physics at the product planning and concept stage.

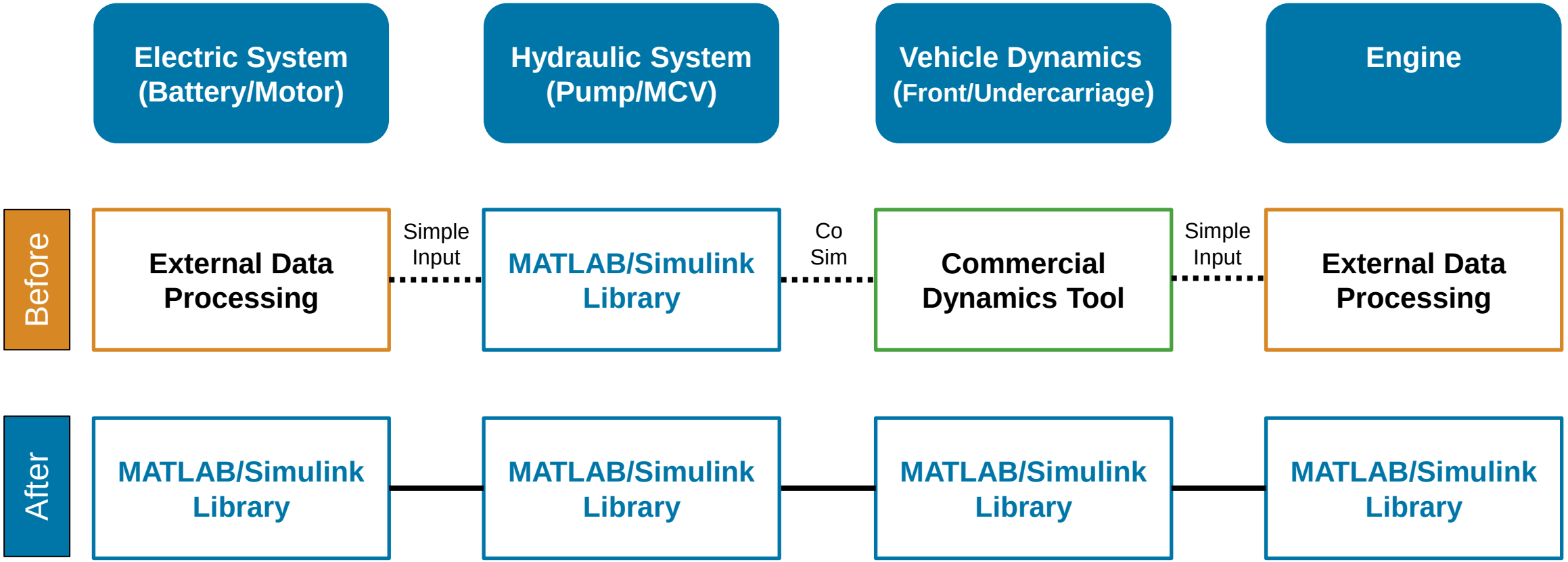


*VPD: Virtual Product Development

Target equipment for system simulation is a 14-ton wheel *PHEV excavator manufactured by HD HYUNDAI. (Especially energy consumption is a key factor for all type of electric vehicles)

*PHEV: Plug-in Hybrid Electric Vehicle (The picture above is different from a real image of target equipment, the 14-ton wheel PHEV, used in this study.)

It is not easy to ensure the reliability of calculation results, and calculation times are so lengthy due to the limitations of using pre-calculated data inputs and Co-simulations. However, these limitations have been overcome by utilizing system simulation with MATLAB/Simulink solutions.

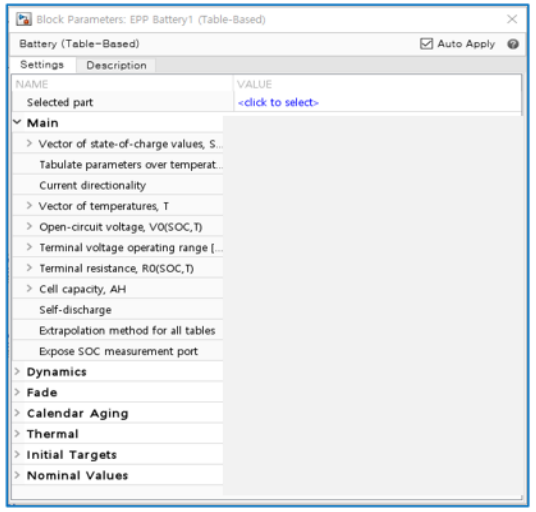


*MCV: Main Control Valve

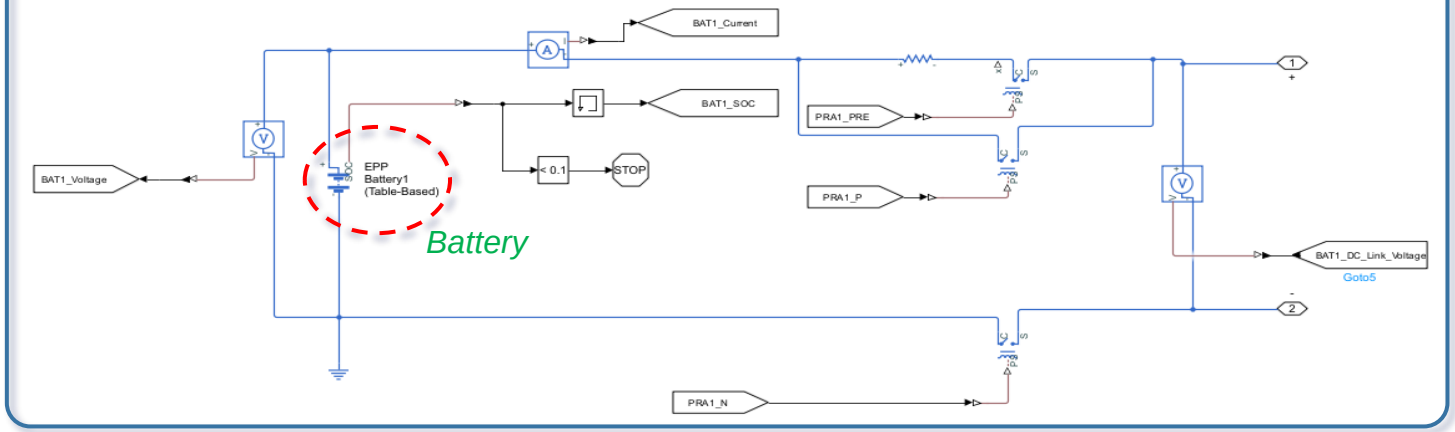
System simulation model including batteries, motors, hydraulics, engine, front structure, and undercarriage structure, is built in MATLAB/Simulink to predict the power performance of an electric excavator in driving and excavation modes.

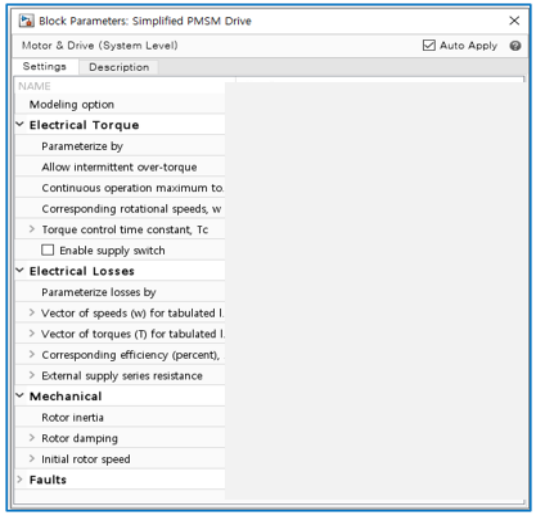
System Simulation Model for Performance Prediction of Electric Excavator using MATLAB/Simulink

Electric model can consider practical energy efficiency. Energy capacity over time(Ampere-hour rating) for the batteries / Speed-torque map and energy efficiency for the motors.

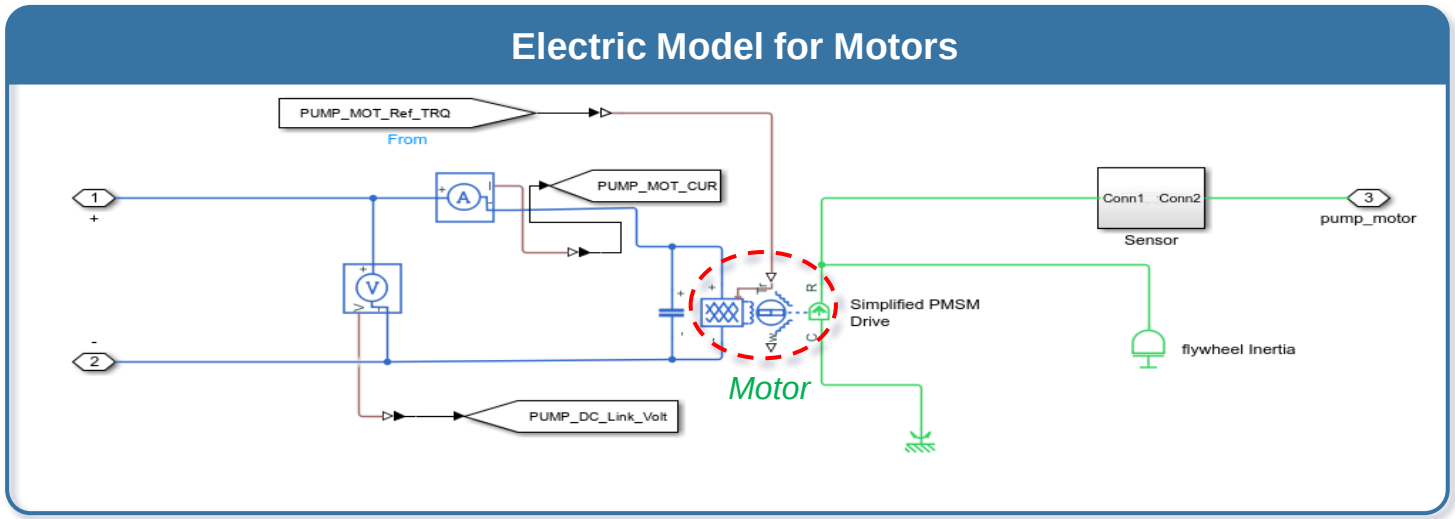


Electric Model for Batteries



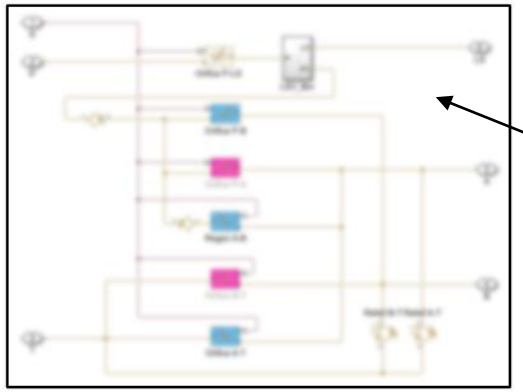


Electric Model for Motors

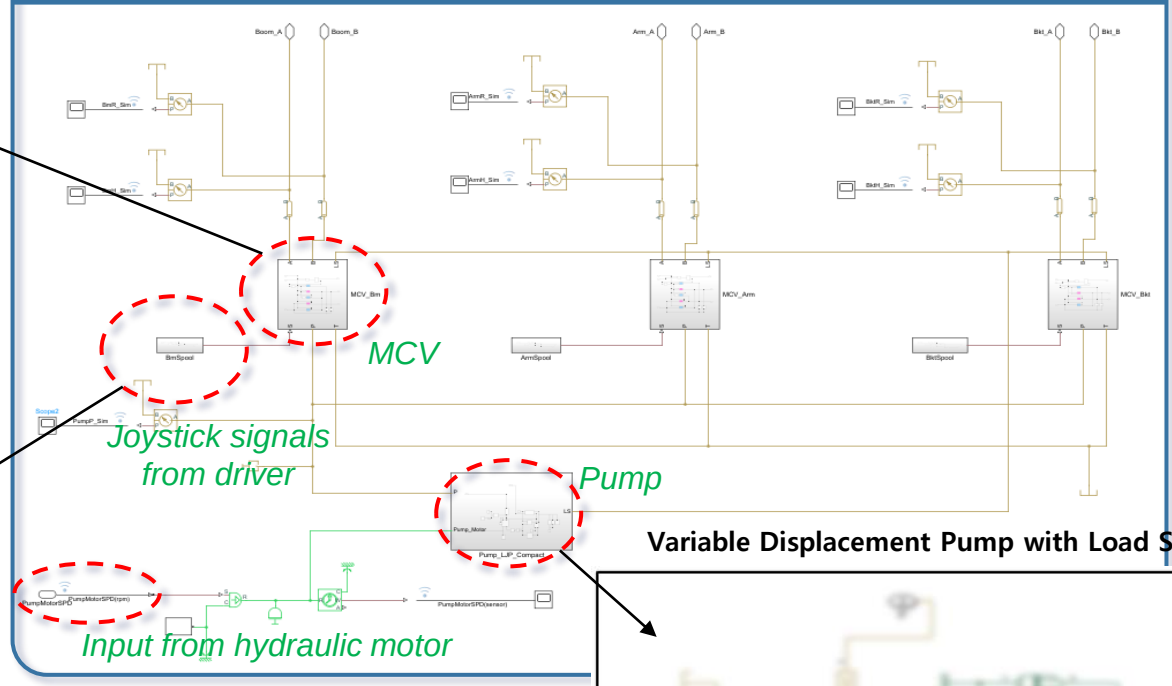


Hydraulics model is built to move boom/arm/bucket by using load-sensing control system with variable displacement pump controlled by *MCV based on the joystick signals from the driver.

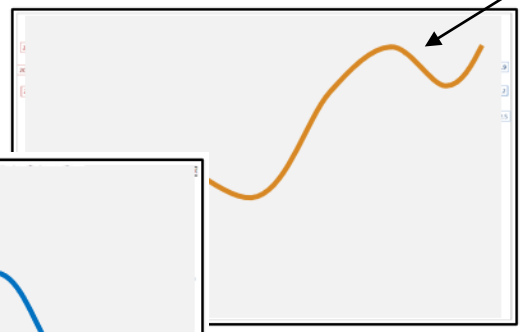
MCV Circuit with Regen



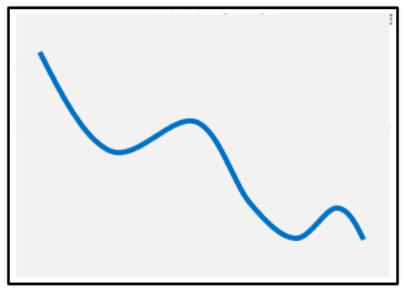
Hydraulics Model for Hydraulic System



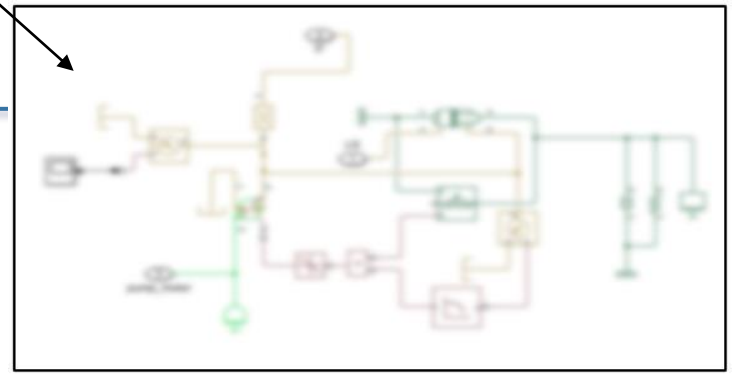
Pilot Control Pressure & Spool Position



Current Sign & Pilot Control Pressure

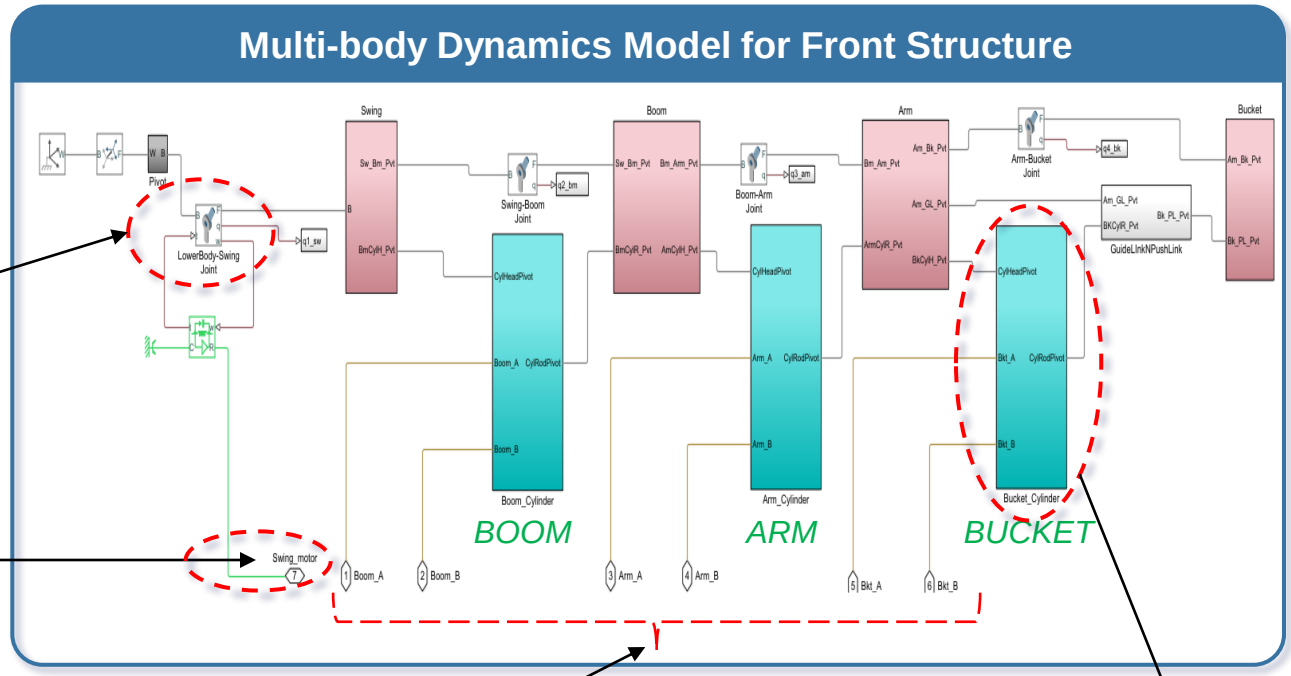


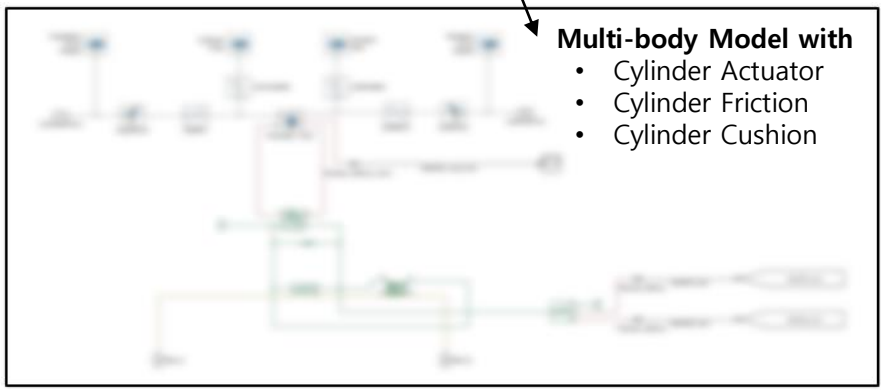
Variable Displacement Pump with Load Sensing



*MCV: Main Control Valve

Multi-body dynamics model for the front structure is built for working mode. Bodies for the boom/arm/bucket, based on cylinders driven by hydraulics, are interconnected through joints to cooperate. Entire front assembly can be rotated by the dedicated swing motor.



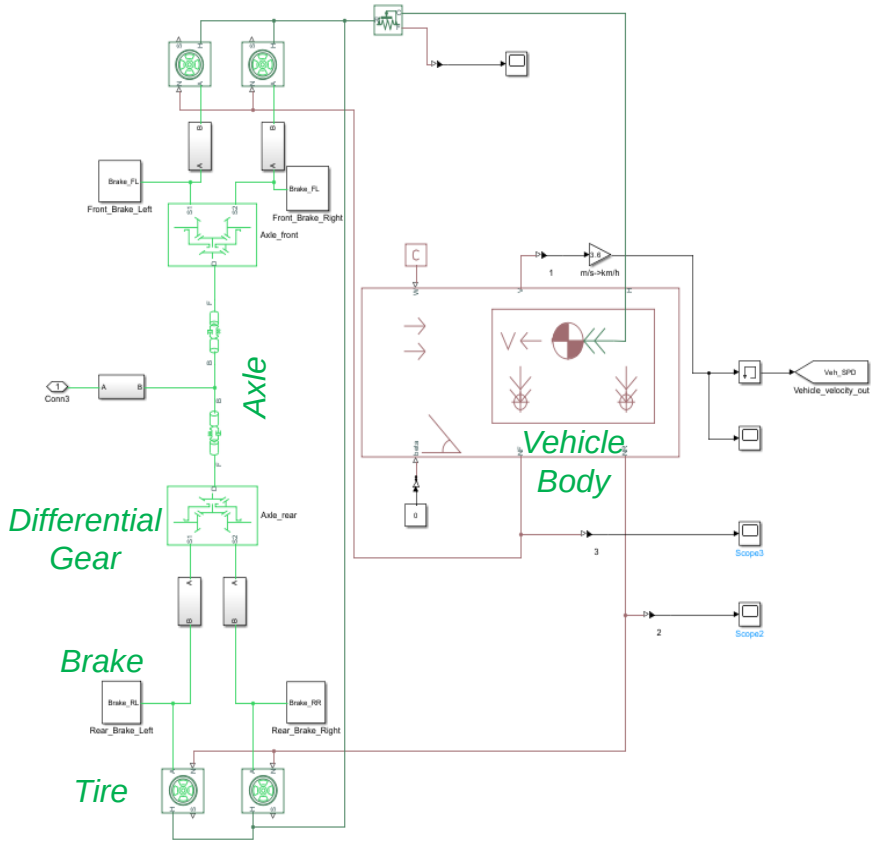


Multi-body Model with

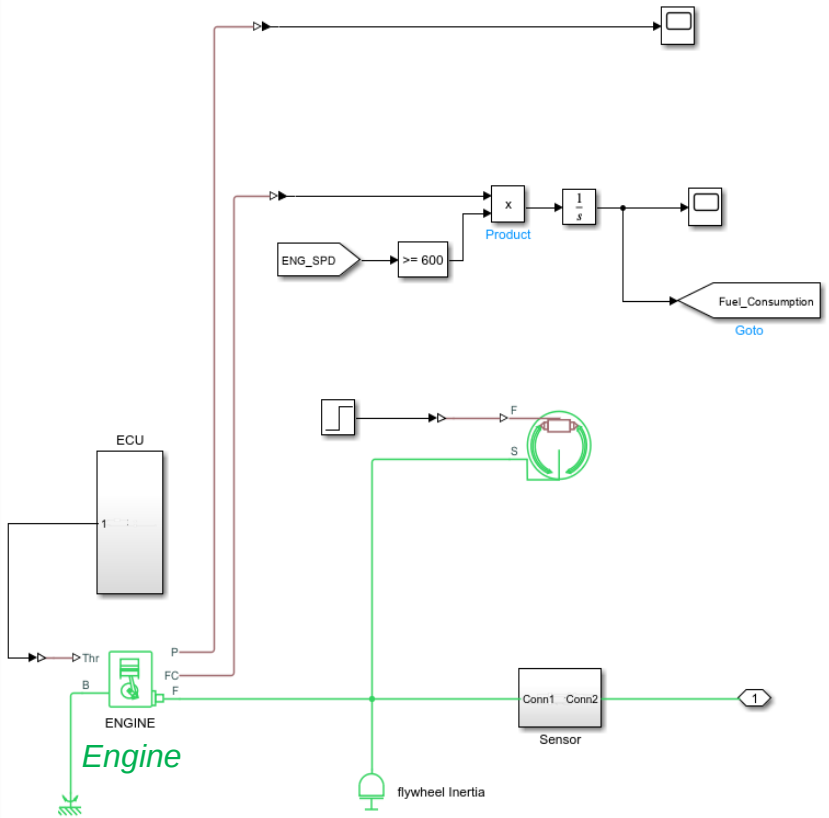
- Cylinder Actuator
- Cylinder Friction
- Cylinder Cushion

Vehicle dynamics model for the undercarriage structure is built for driving mode. Driveline model consists of axles, differential gears, brakes, tires, and vehicle body. As an auxiliary component, engine model is built to operate generator considering the speed-torque map for the engine.

Vehicle Dynamic Model for Undercarriage Structure



Auxiliary Engine Model for Generator

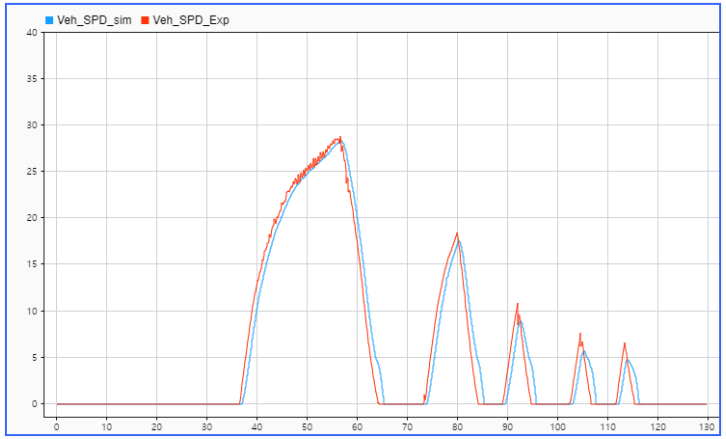


System simulation results are validated based on measurement results for both working and driving mode.

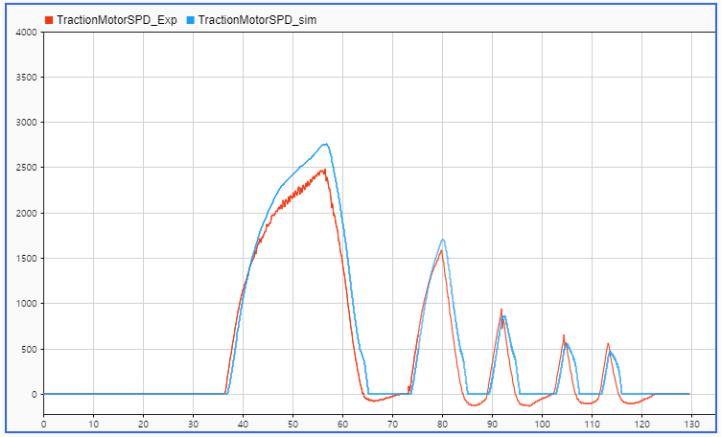
Performance Results for Driving Mode

Measurement
Simulation

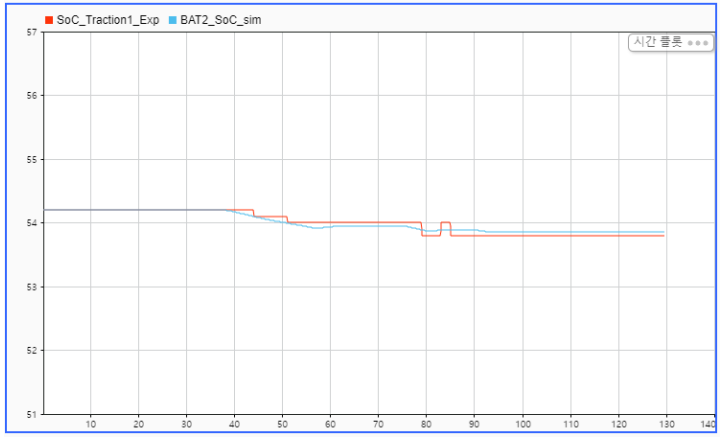
Vehicle Speed



Travel Motor Speed

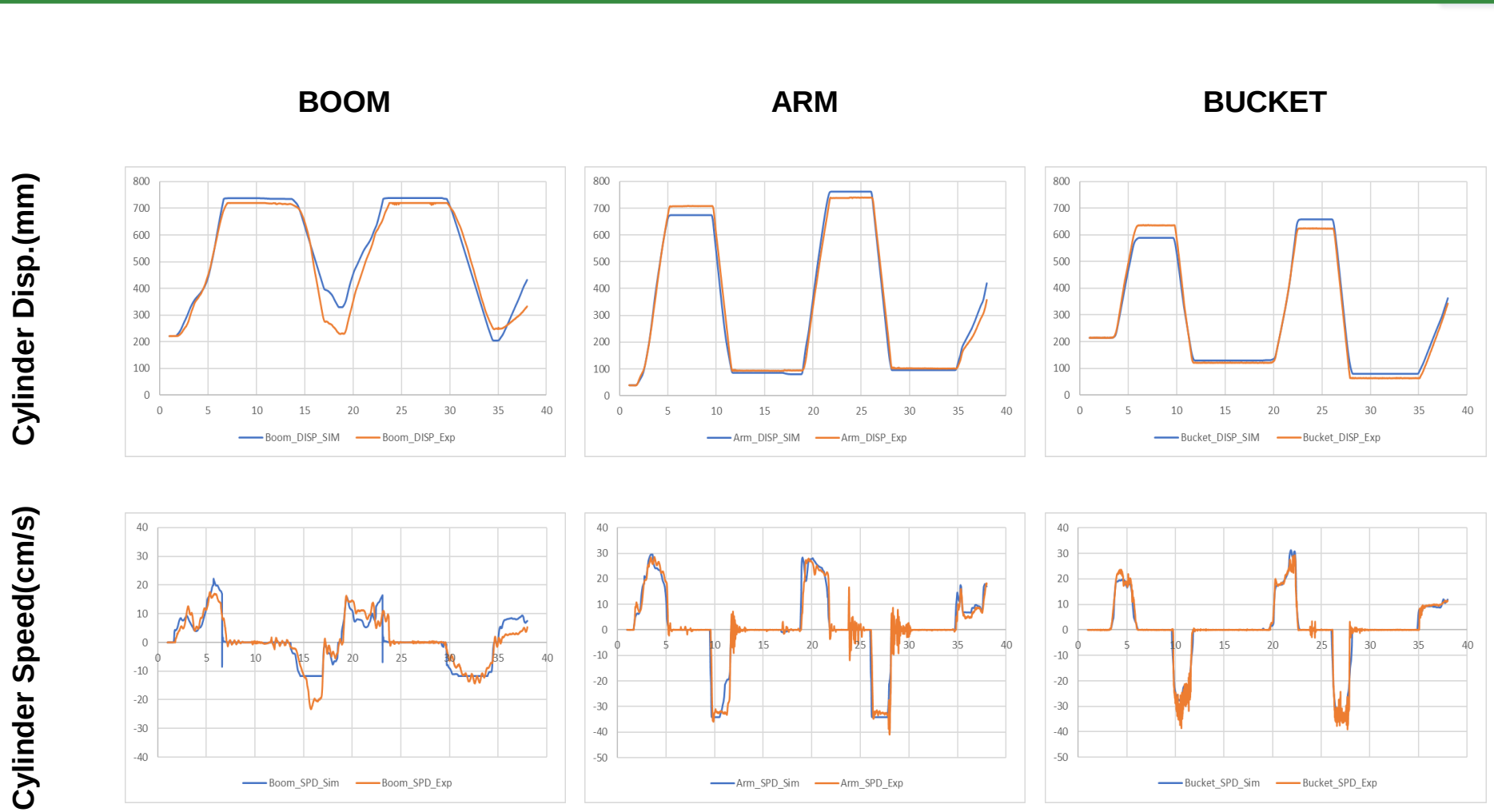


Battery SoC



System simulation results are validated based on measurement results for both working and driving mode.

Performance Results for Working Mode



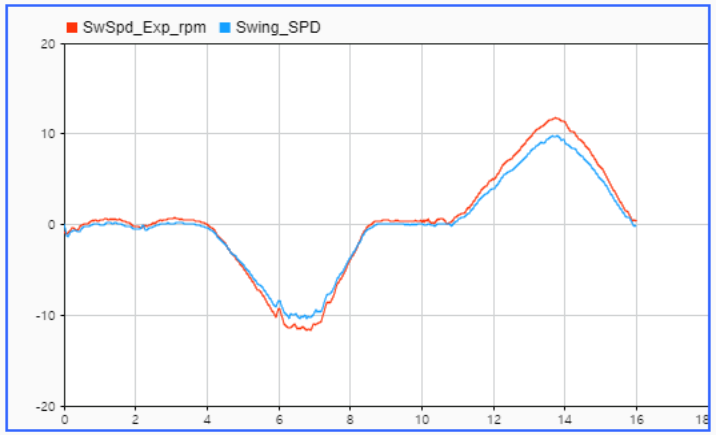
System simulation results are validated based on measurement results for both working and driving mode.

Performance Results for Working Mode (Continued)

Measurement
Simulation

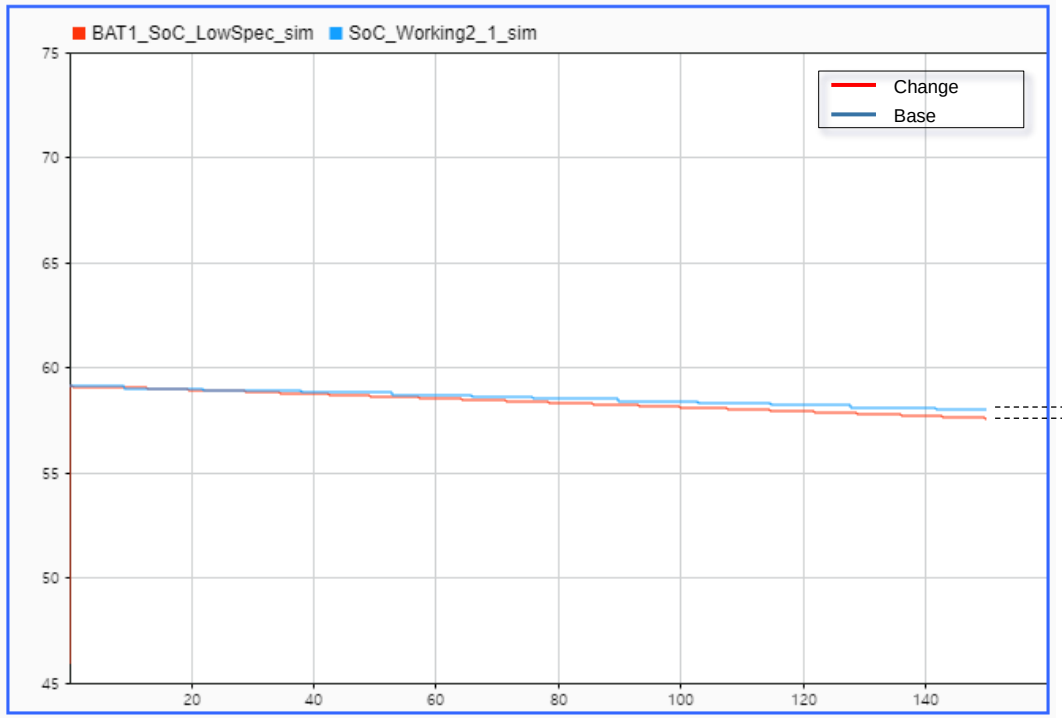
Swing Motor Speed

Swing Speed

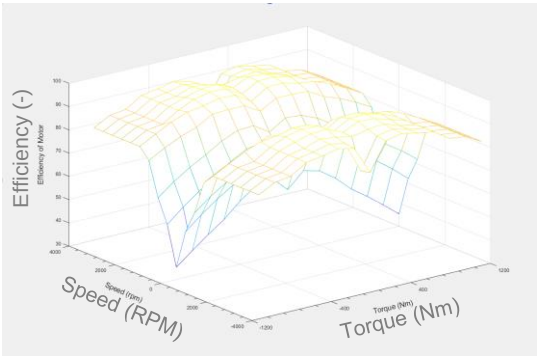


Using the developed system simulation model for electric excavator, it is possible to predict changes in power performance when changing system specifications.

SOC_{init} = 59.1 % , 180° Digging (150 [s])



Efficiency Map for Hydraulic Motor

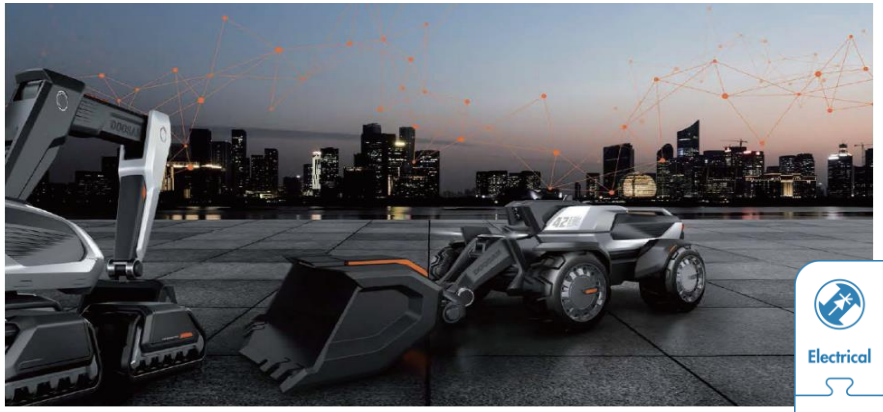


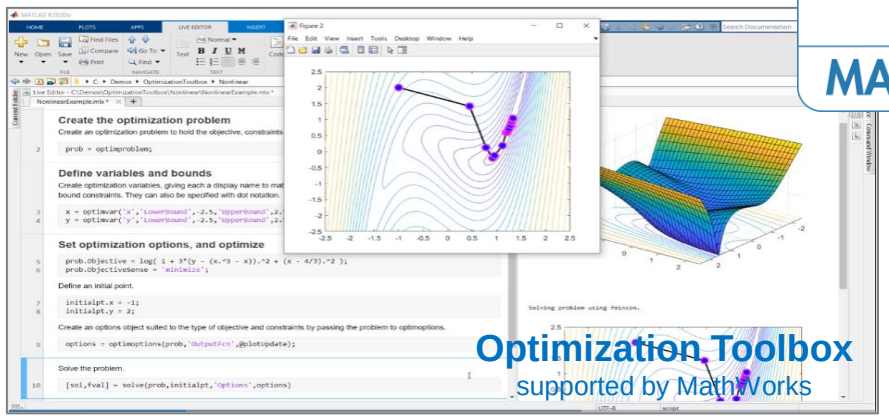
additional energy consumption in batteries:
0.08% during 150sec

for 4 hour working standard:
decrease by approximately 17minutes

Developed method is being used to improve energy consumption for *EV construction equipment with Optimization Toolbox among MATLAB/Simulink and will be extended to model-based system engineering approach over the entire development process from concept to prototype.

Improving Energy Consumption for EV with Optimization





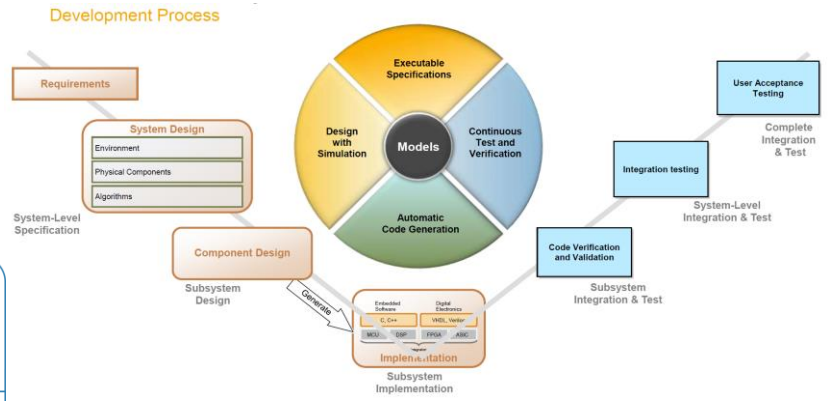
Electrical | Battery | Fluids | Multibody | Driveline

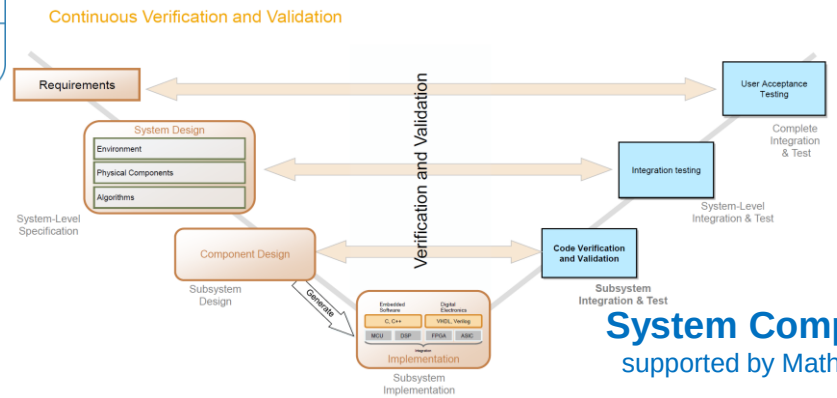
Simscape

MATLAB & Simulink

Optimization Toolbox
supported by MathWorks

Extending to Model-Based System Engineering





System Composer
supported by MathWorks

*EV: Electric Vehicle (BEV: Battery Electric Vehicle, FCEV: Fuel Cell Electric Vehicle)

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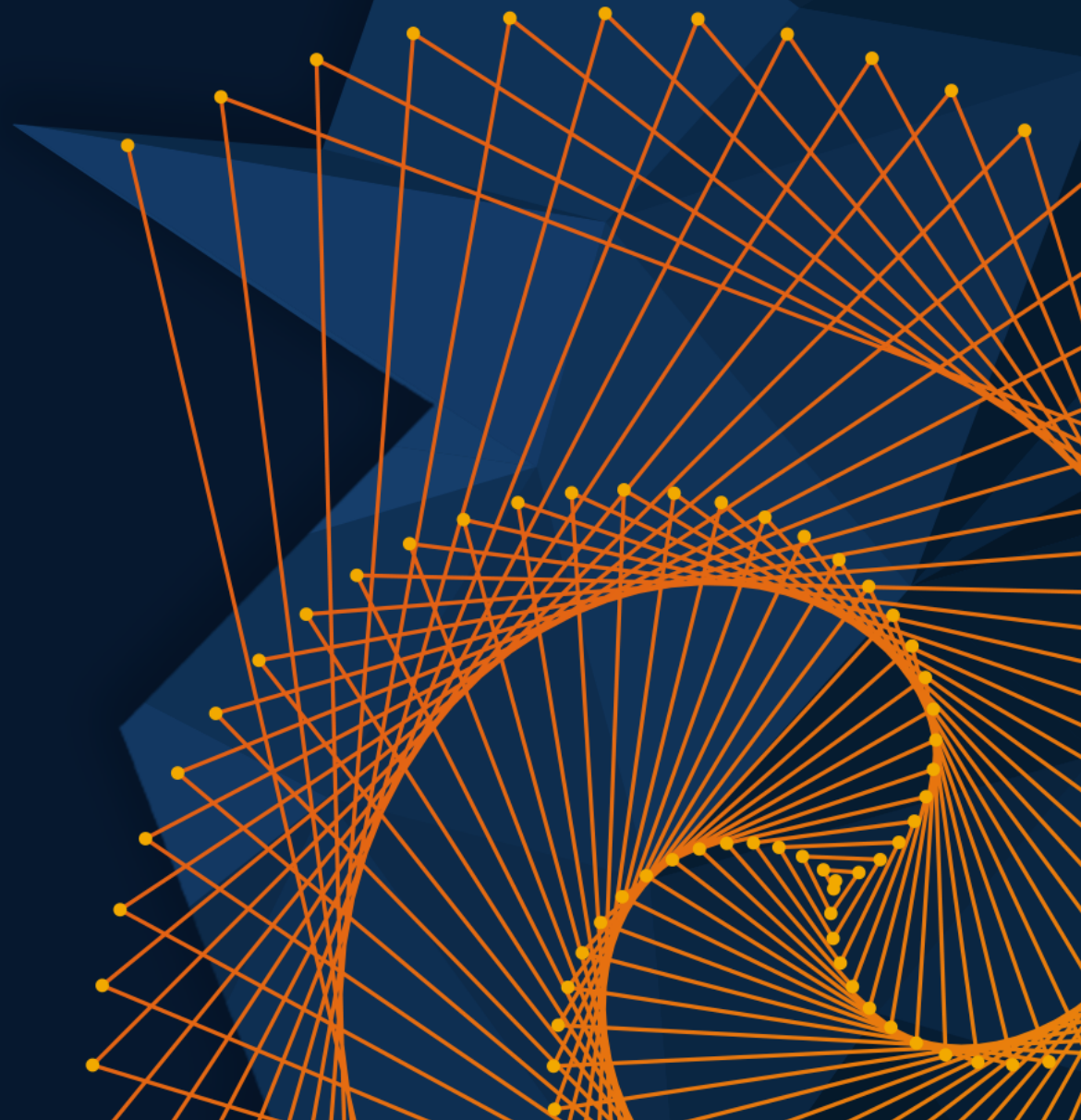

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