2020 MathWorks 中国汽车年会

基于参考应用程序 快速开发虚拟电动汽车模型

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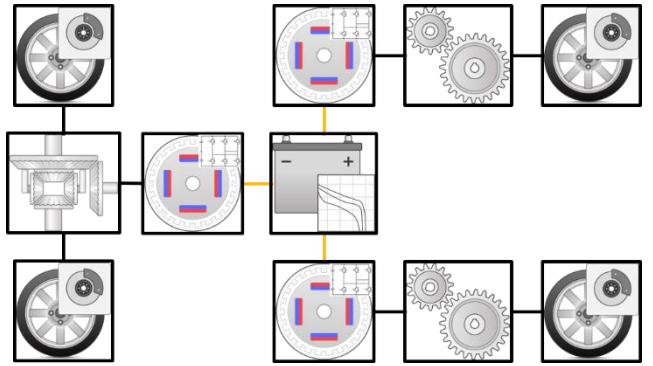
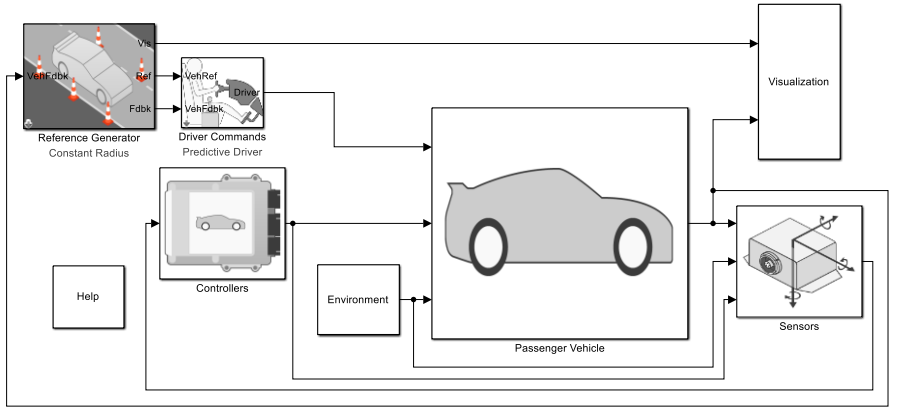
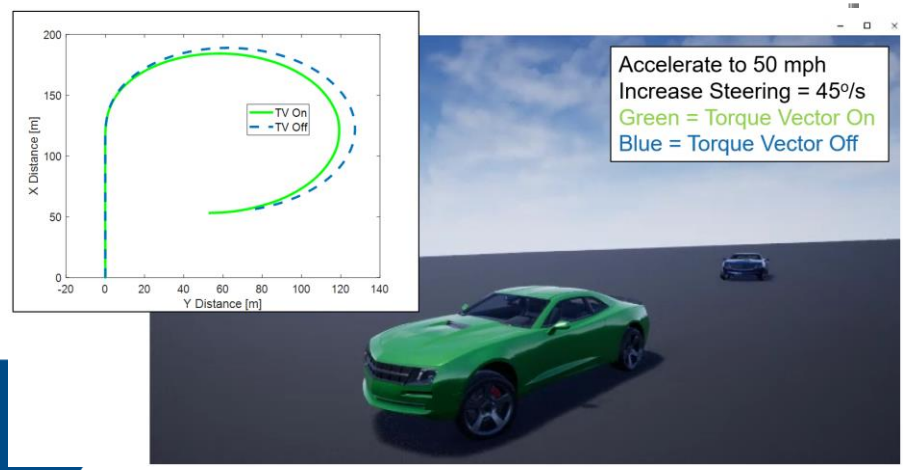
内容提要

- MathWorks 在虚拟车辆仿真上的应用:
  - 使用Powertrain Blockset 和 Vehicle Dynamics Blockset快速评估电气化动力总成
  - 参考应用提供了模型构架和测试用例的模板
  - 单个模型用于支持多种基于模型设计的活动



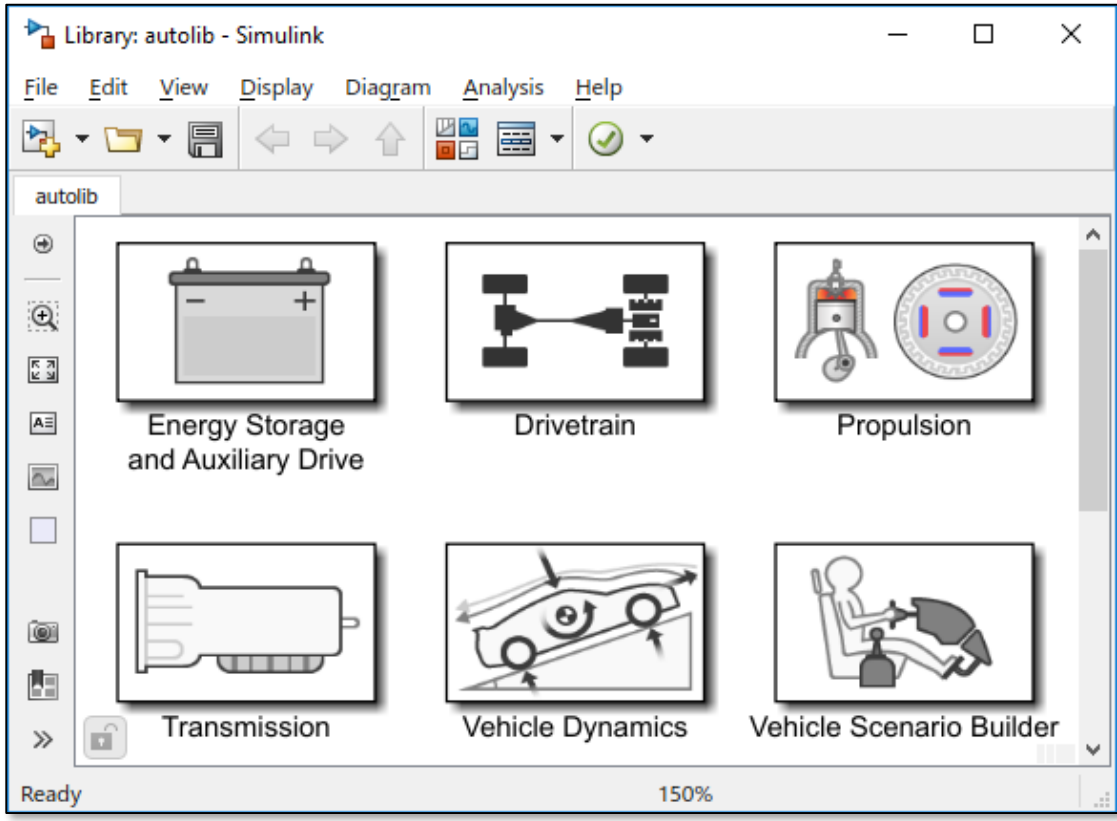




Powertrain Blockset

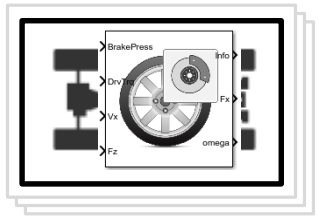
- 目标:
  - 为工程师建立**被控对象/控制器**模型提供良好的起点
  - 提供**开放**的模型和详细的文档说明
  - 提供**快速运行**的模型，可与主流的HIL系统配合使用

模块库

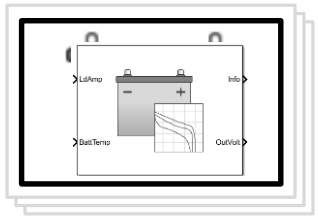


降低基于模型设计的准入门槛

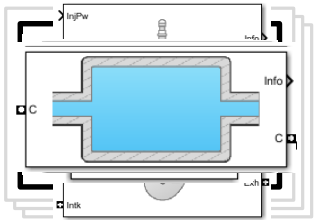
R2016b MathWorks



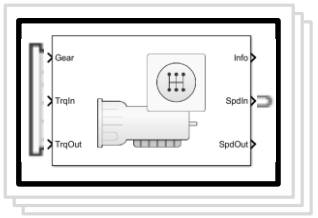
Drivetrain



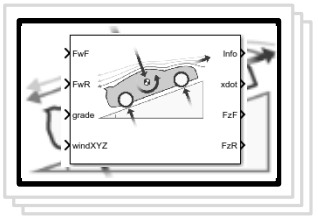
Energy Storage and Auxiliary Drive



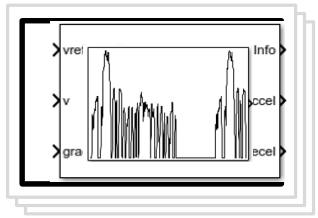
Propulsion



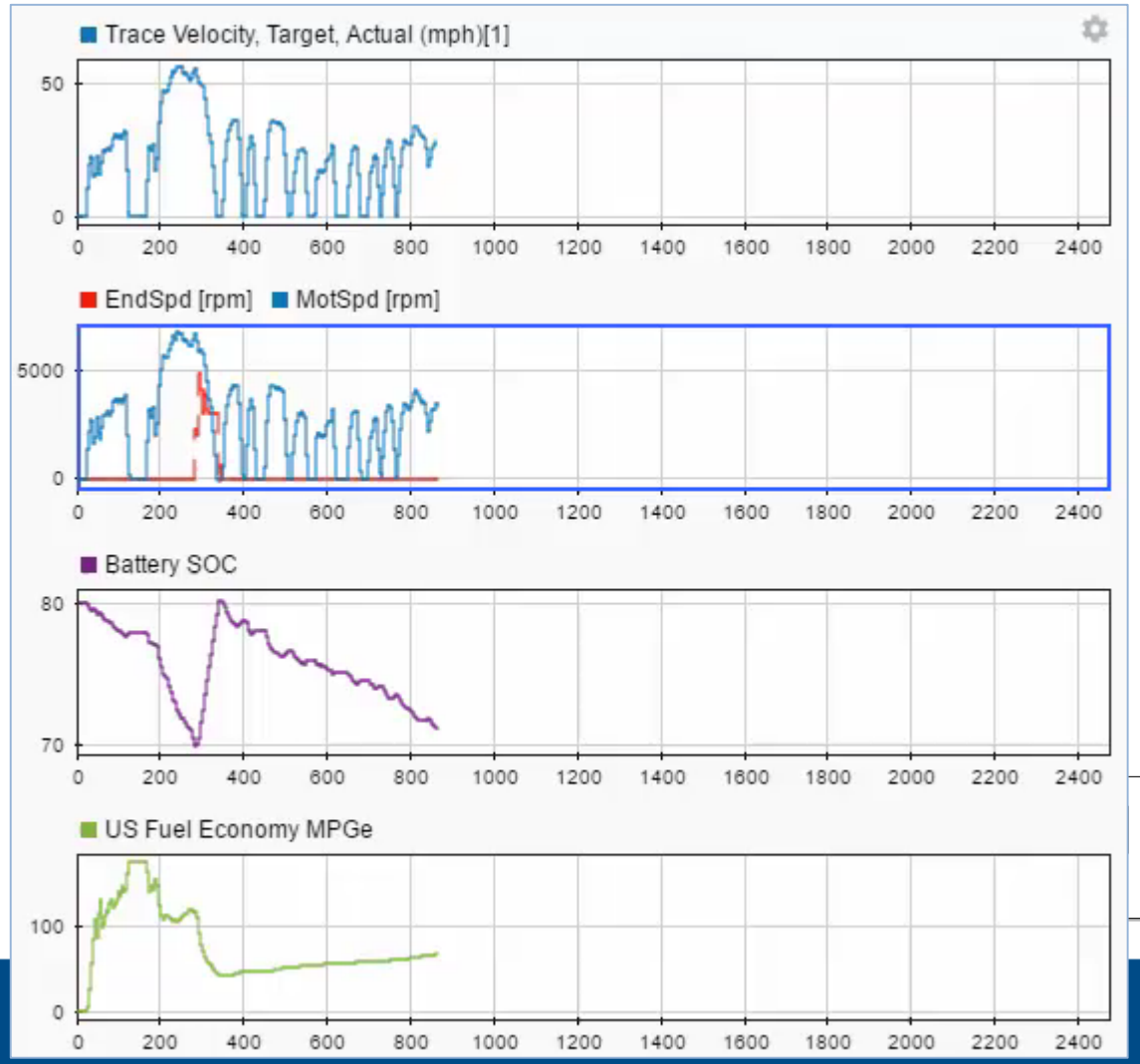
Transmission

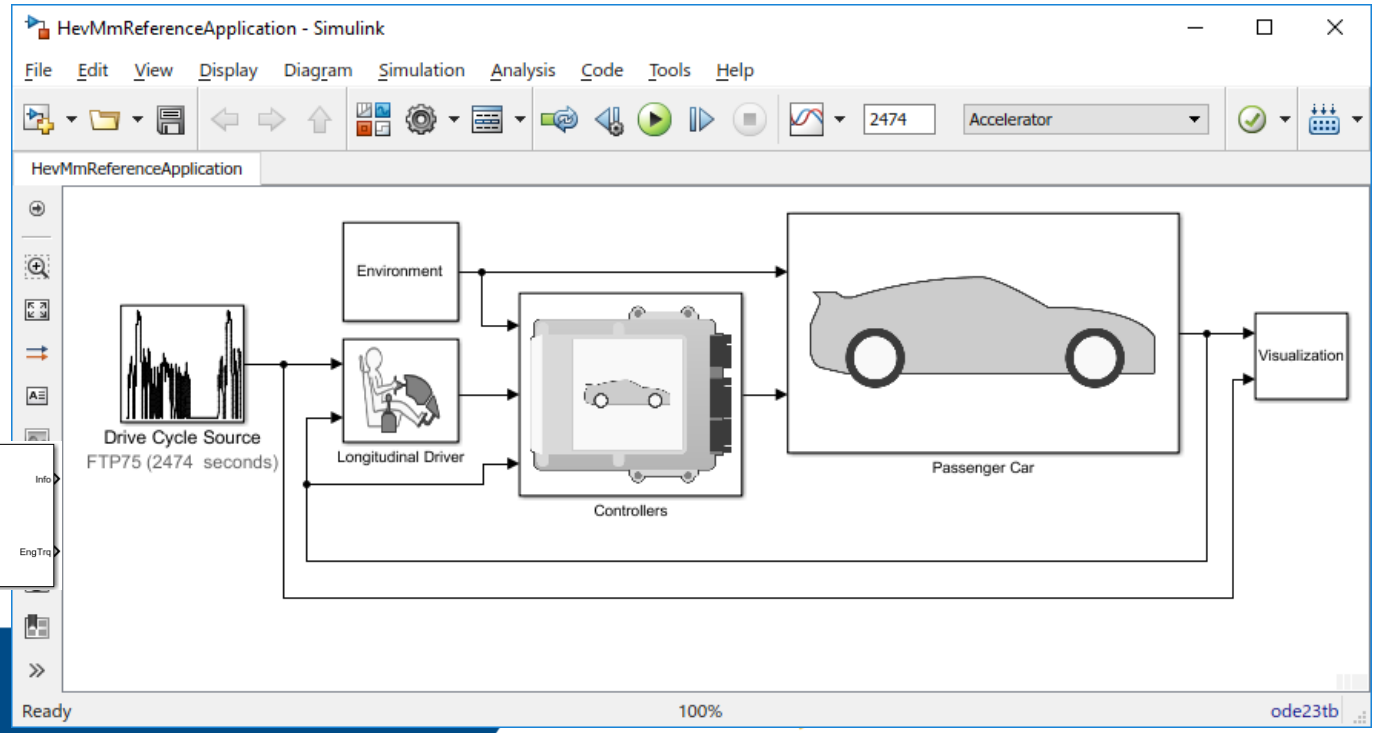


Vehicle Dynamics



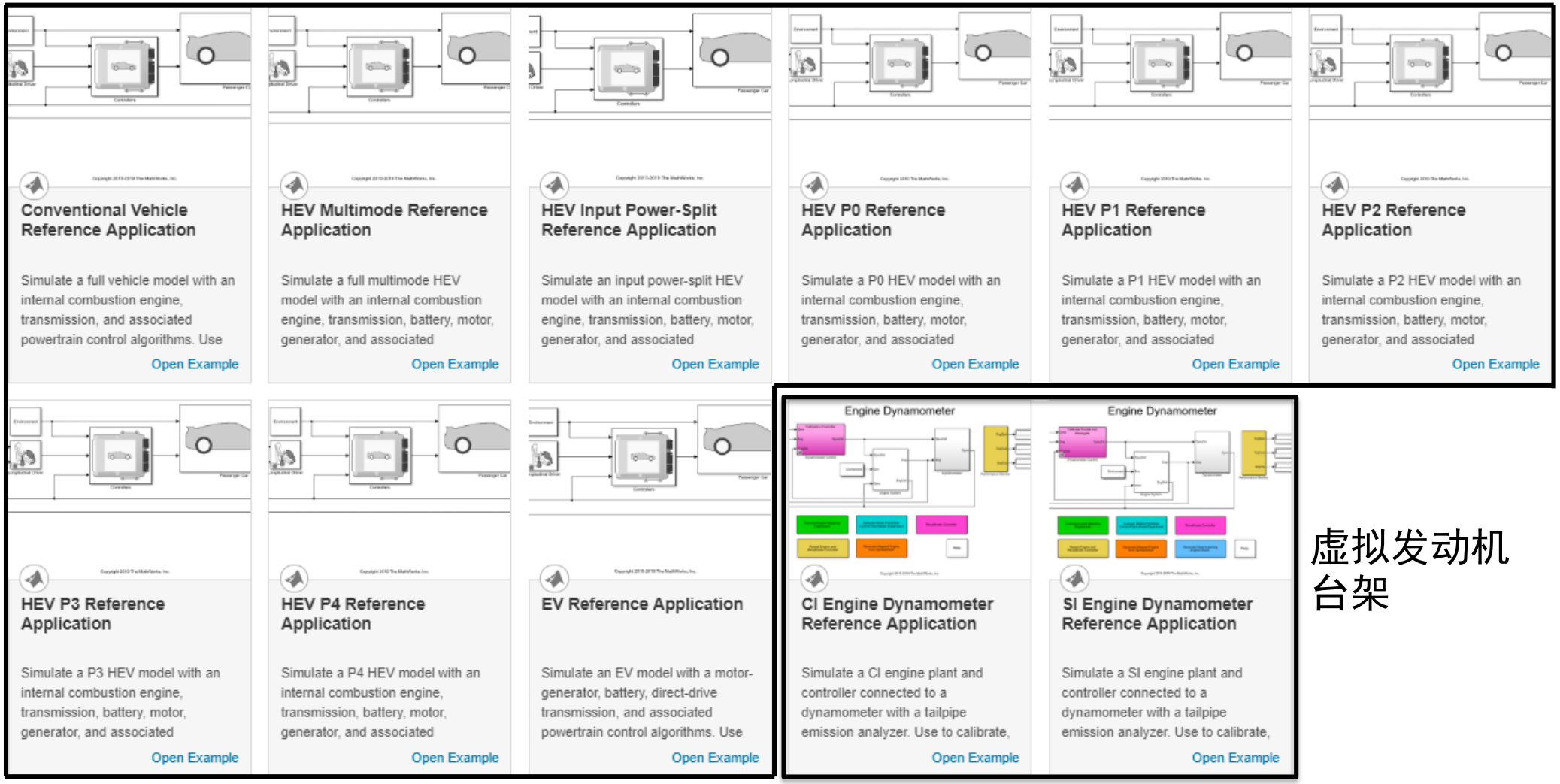
Vehicle Scenario Builder





参考应用

虚拟车辆模型

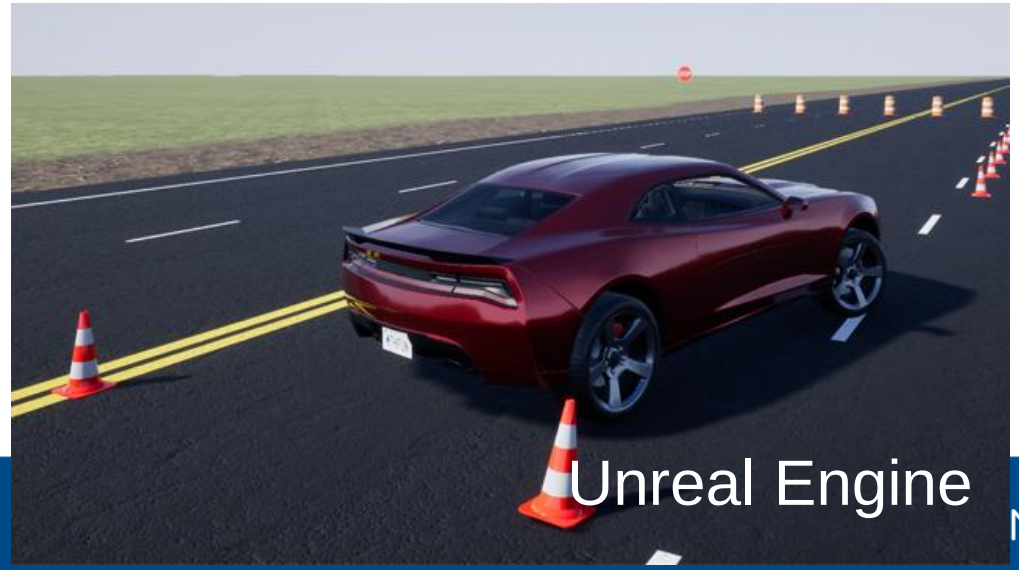


虚拟发动机台架

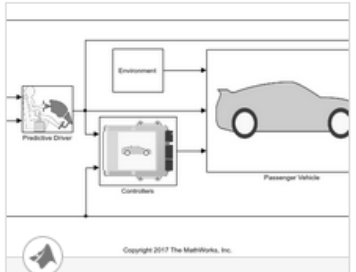
Vehicle Dynamics Blockset

R2018a

模块库



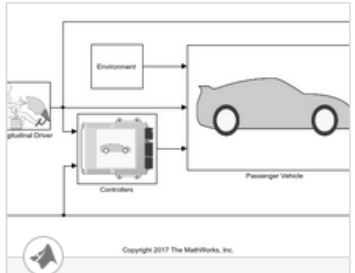
预制的参考应用



Double-Lane Change Reference Application

Simulate a full vehicle dynamics model undergoing a double-lane change maneuver according to standard ISO 3888-2. You can

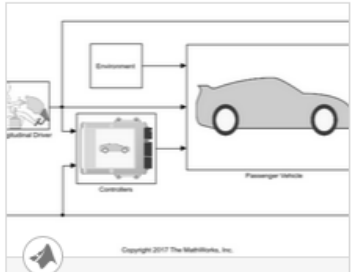
Open Example



Increasing Steering Reference Application

Simulate a full vehicle dynamics model undergoing a slowly increasing steering maneuver according to standard SAE J266.

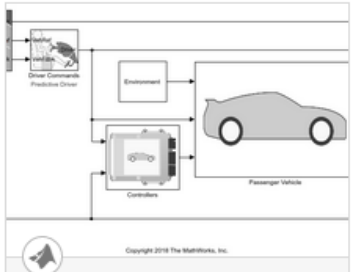
Open Example



Swept Sine Steering Reference Application

Simulate a full vehicle dynamics model undergoing a swept-sine steering maneuver. You can create your own versions, providing a

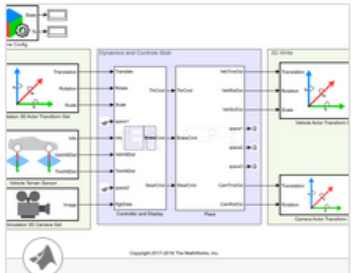
Open Example



Constant Radius Reference Application

Simulate a full vehicle dynamics model undergoing a constant radius maneuver. You can create your own versions, providing a framework to

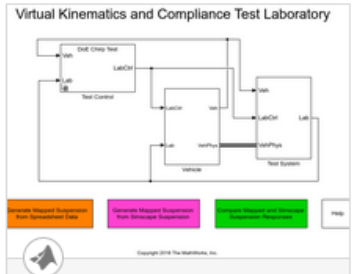
Open Example



Scene Interrogation with Camera and Ray Tracing Reference Application

Interrogate a 3D scene with a vehicle dynamics model by using a camera and ray tracing reference application project.

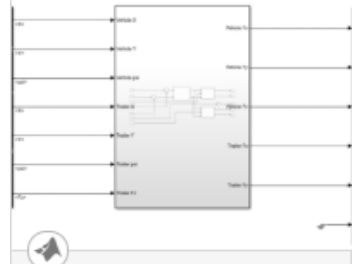
Open Example



Kinematics and Compliance Virtual Test Laboratory Reference...

Generate optimized suspension parameters for the vehicle dynamics suspension blocks.

Open Example



Three-Axle Tractor Towing a Trailer

Simulate a three-axle tractor towing a three-axle trailer.

Open Example

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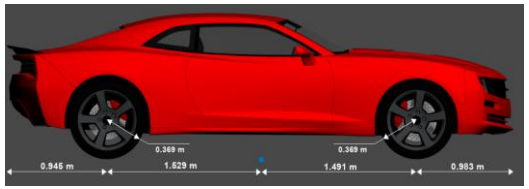
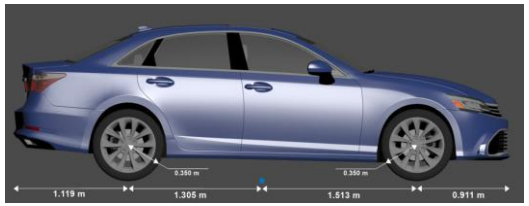
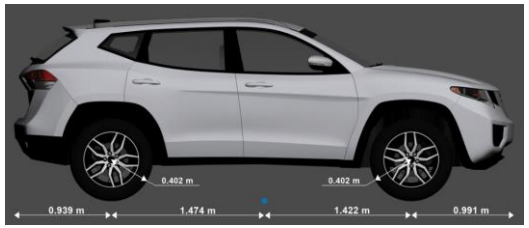
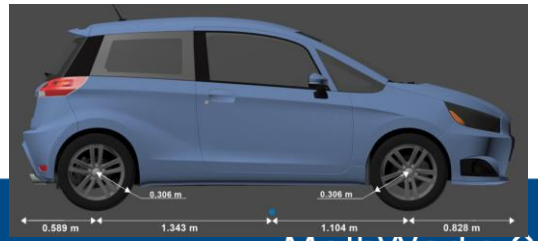
Vehicle Dynamics Blockset

- 使用虚幻引擎的3D逼真的环境（Epic Games）
- 预制场景和车辆类型

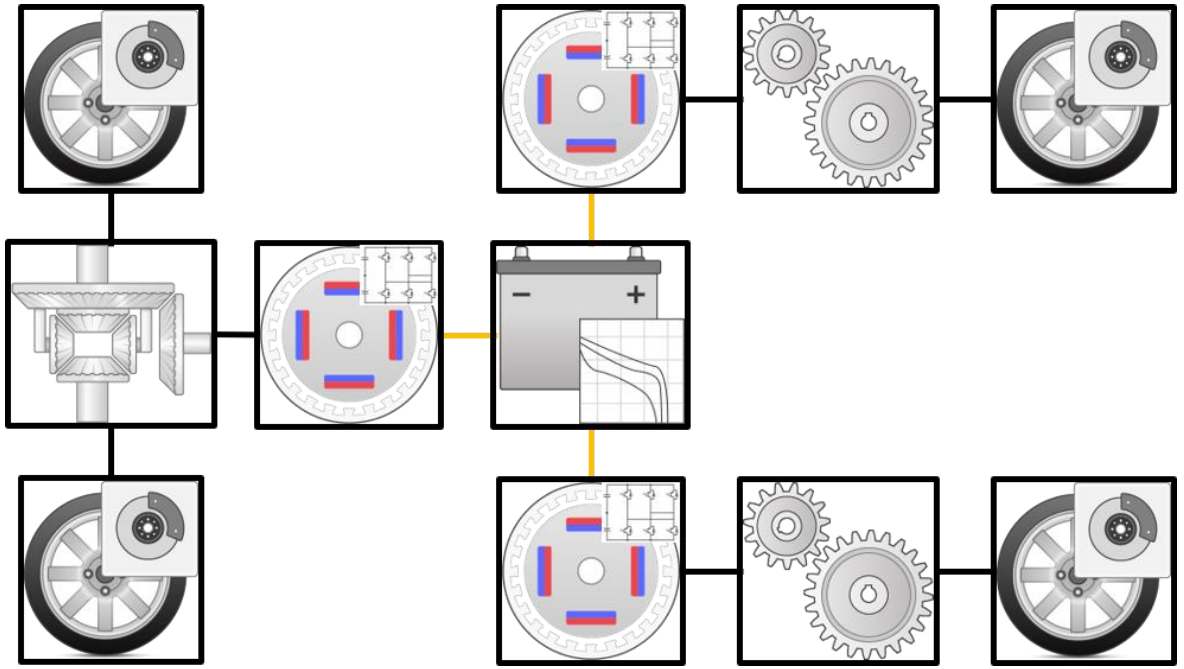




电动动力总成选择案例研究

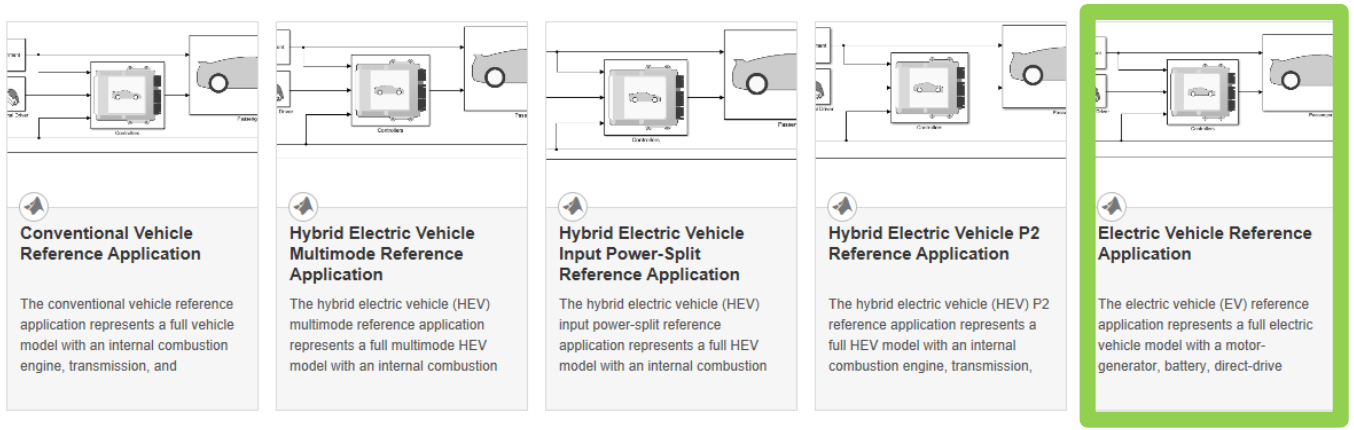
- 评估三电机纯电动汽车动力总成

- 使用一个模型开发和评估
  1. 整车能量管理的监督控制
  2. 前后轴传动比的优化
  3. 同轴的两个轮毂电机扭矩分配
  4. 集成详细的BMS/电池模型到系统级模型中
  5. 使用单踏板驱动算法的驾驶员在环功能



参考应用工作流

1. 选择一个车辆构型
   - 选择一个参考应用作为起点

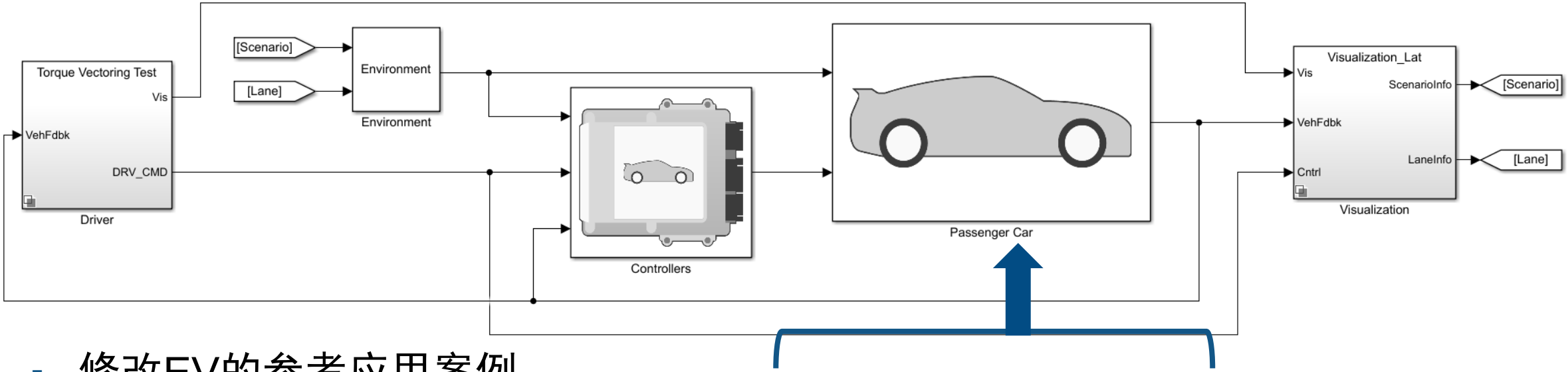


2. 自定义被控对象模型
   - 参数化组件
   - 自定义现有子系统
   - 使用可变子系统添加自定义的子系统

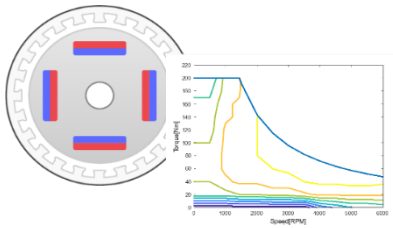
3. 自定义控制器
   - 参数化组建
   - 自定义控制逻辑
   - 使用可变子系统添加自己的控制子系统

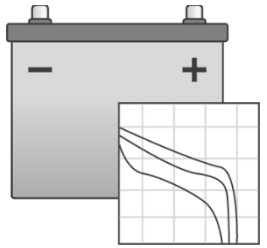
4. 执行闭环测试
   - 敏感度分析
   - 设计优化
   - MIL / SIL / HIL 测试

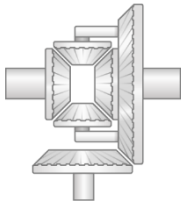
动力总成被控对象模型

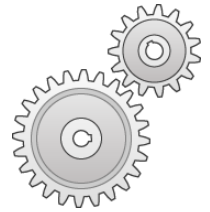


- 修改EV的参考应用案例
  - 3个永磁同步电机
  - 电池
  - 前差速器/后轴齿轮组







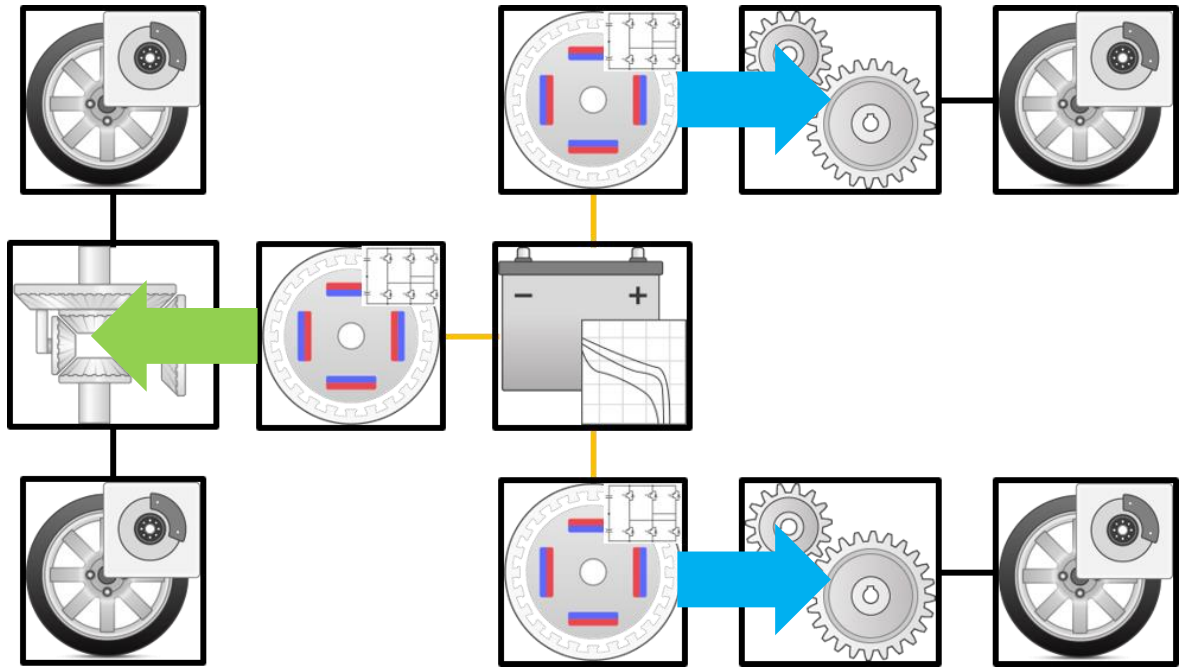


1. EV 能量管理策略(Energy Management System)

- 需要能量管理策略控制电机的前/后扭矩分配

- 对所需的能量管理策略仿真
  - 不同驾驶循环下的能耗
  - 性能 (i.e. 0-100 km/h)

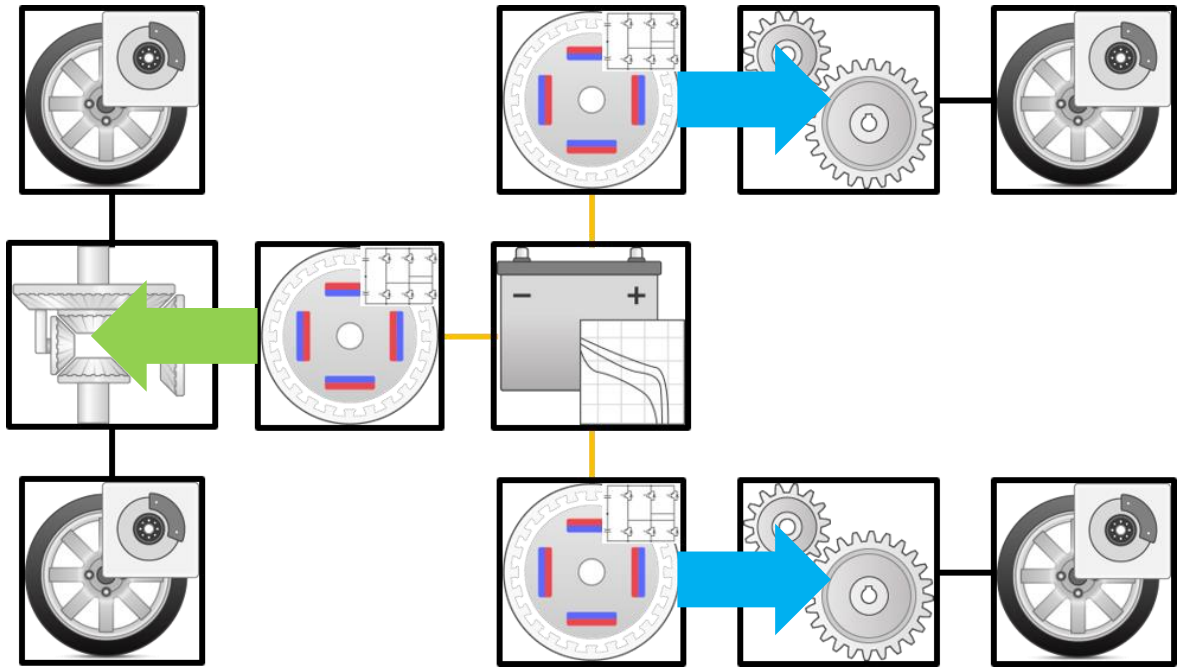
$$T_{demand} = T_{mot,f} + T_{mot,r}$$



1. EV 能量管理策略(Energy Management System)

- 瞬时优化算法
  - 动力源 （电机）的扭矩（或功率）

$$T_{demand} = T_{mot,f} + T_{mot,r}$$



  - 受到以下约束:

$$\tau_{min}(\omega) \leq \tau_{act} \leq \tau_{max}(\omega)$$
$$P_{chg}(SOC) \leq P_{batt} \leq P_{dischg}(SOC)$$
$$I_{chg}(SOC) \leq I_{batt} \leq I_{dischg}(SOC)$$

  - 尽量减少能源消耗， 维持驾驶性

  - 类似于混动车辆控制中的“等效油耗最低算法(Equivalent Consumption Minimization Strategy)”

EV 能量管理策略(EMS)实现过程

每个控制器时间步执行一次

1. 创建扭矩矢量

$$\begin{bmatrix} -Min\ Rear\ Torque \\ \vdots \\ +Max\ Rear\ Torque \end{bmatrix}$$

2. 检查约束条件，确定不可行条件

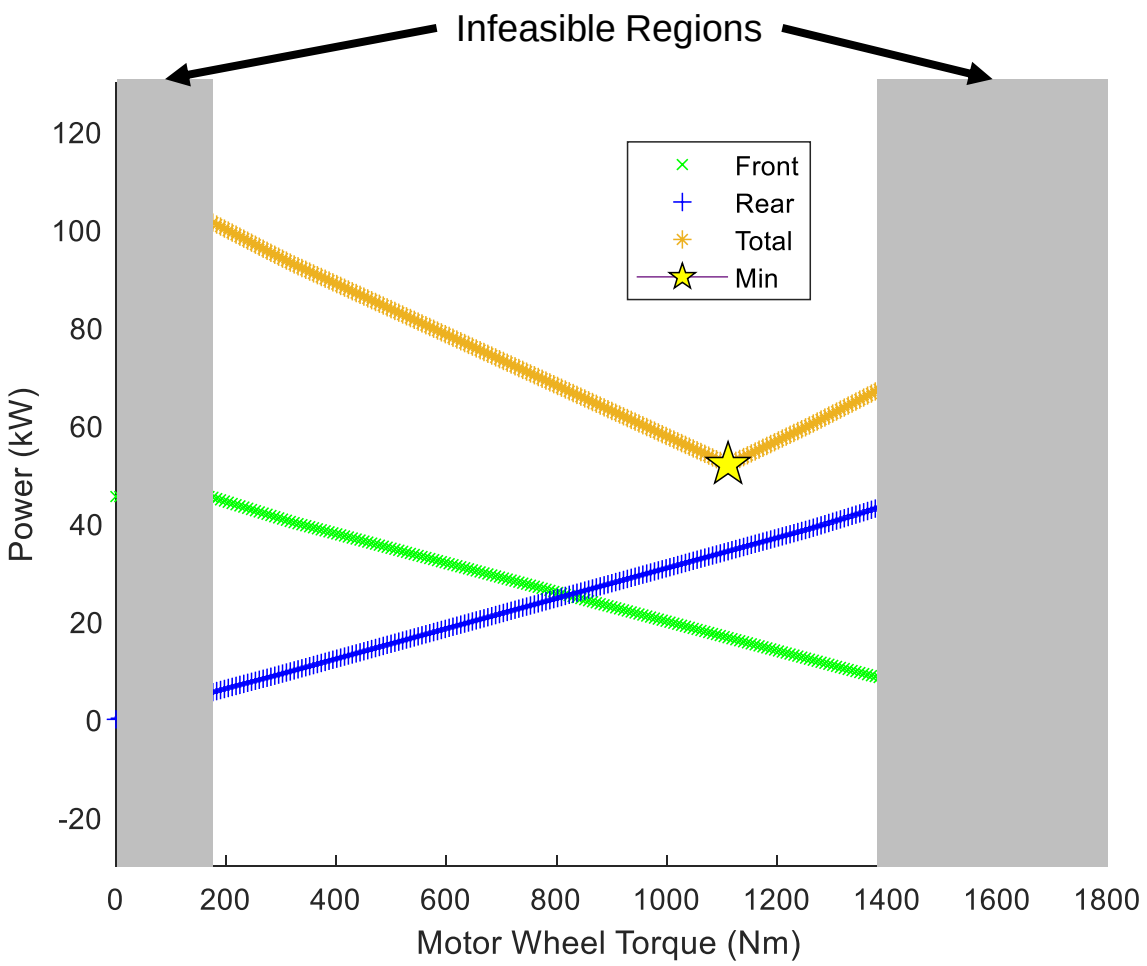
$$\tau_{min}(\omega) \leq \tau_{act} \leq \tau_{max}(\omega)$$
$$P_{chg}(SOC) \leq P_{batt} \leq P_{dischg}(SOC)$$
$$I_{chg}(SOC) \leq I_{batt} \leq I_{dischg}(SOC)$$
$$\tau_{demand} = \tau_{front} + \tau_{rear}$$

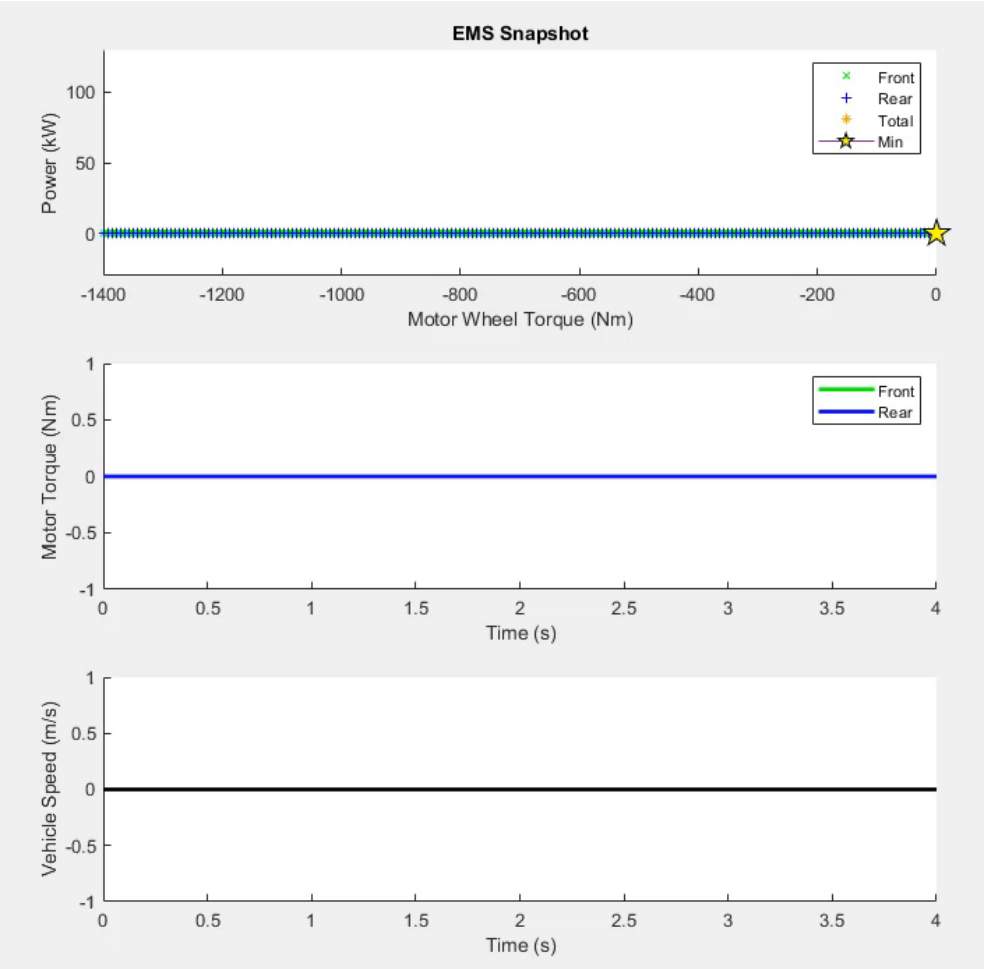
3. 计算并最小化目标函数（电池耗电量）

$$\min_{\tau_{rear}} P_b(\tau_{rear})$$

EV 能量管理策略(EMS)实现过程

某时间点的EMS快照





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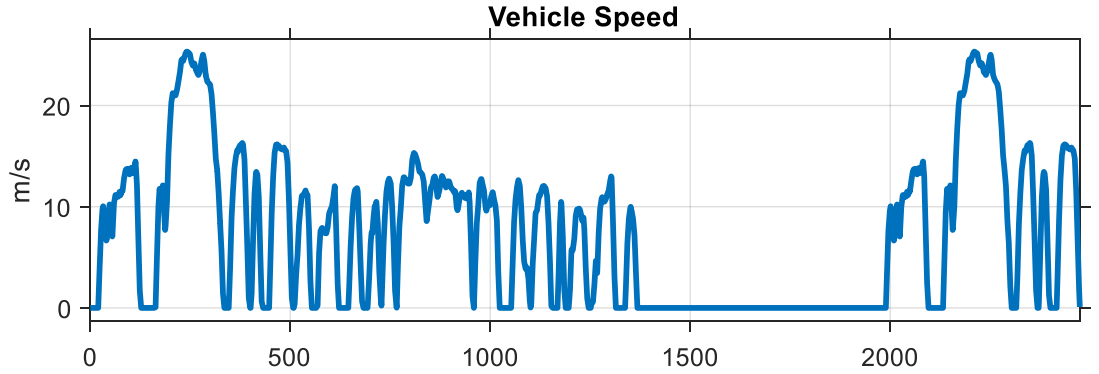
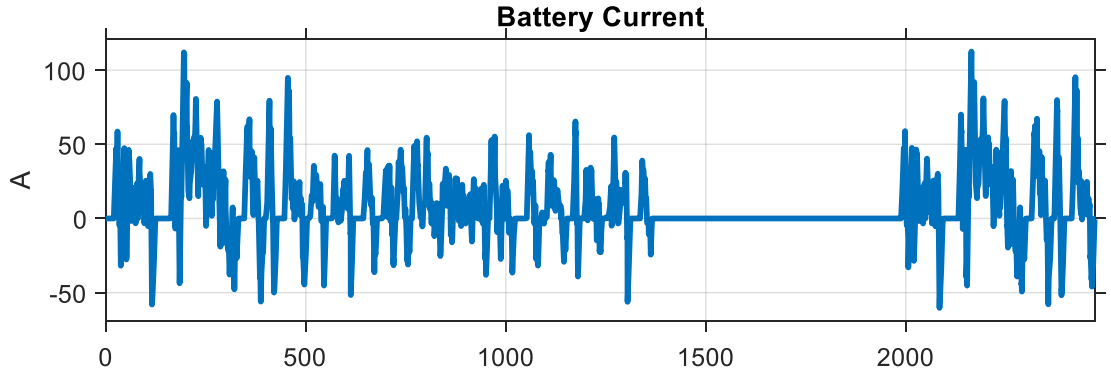
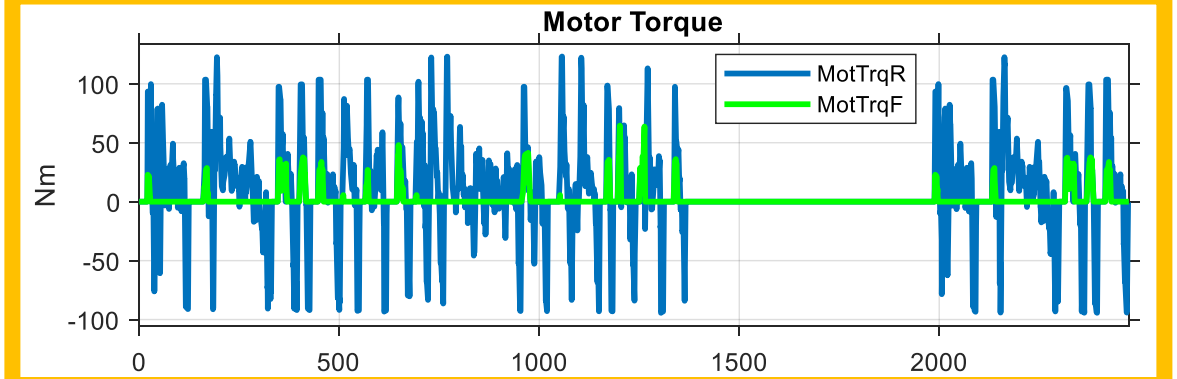
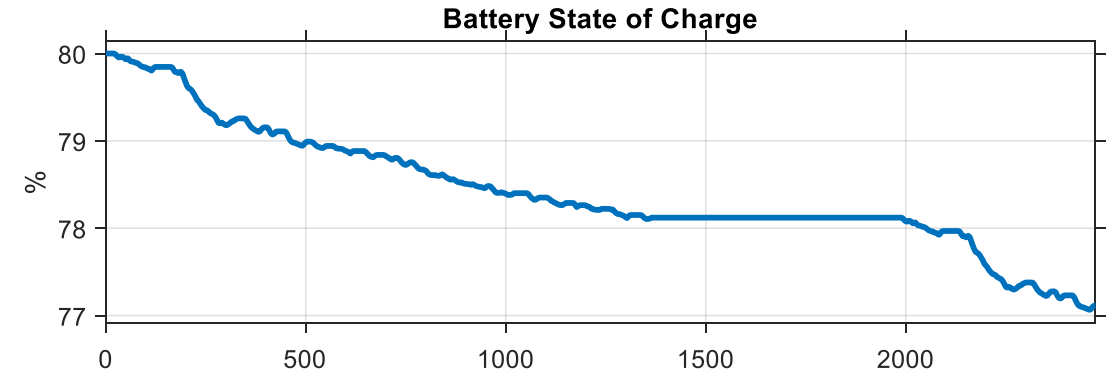
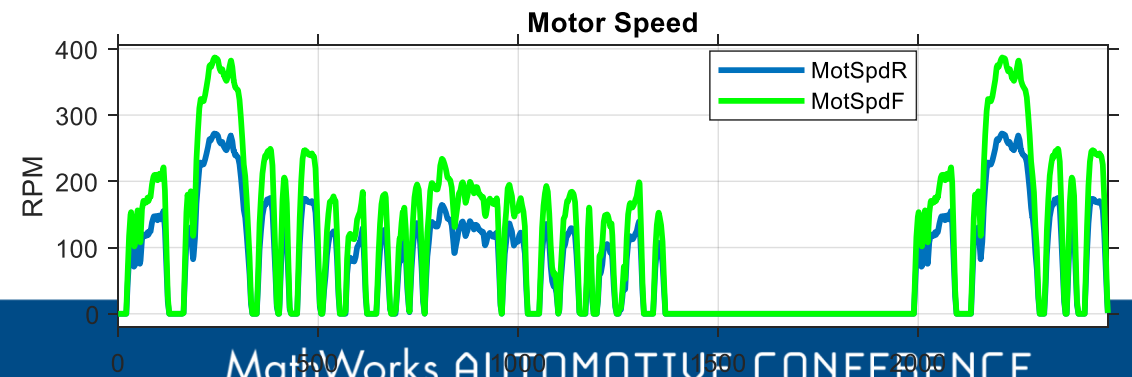
EV 能量管理策略(EMS)实现过程

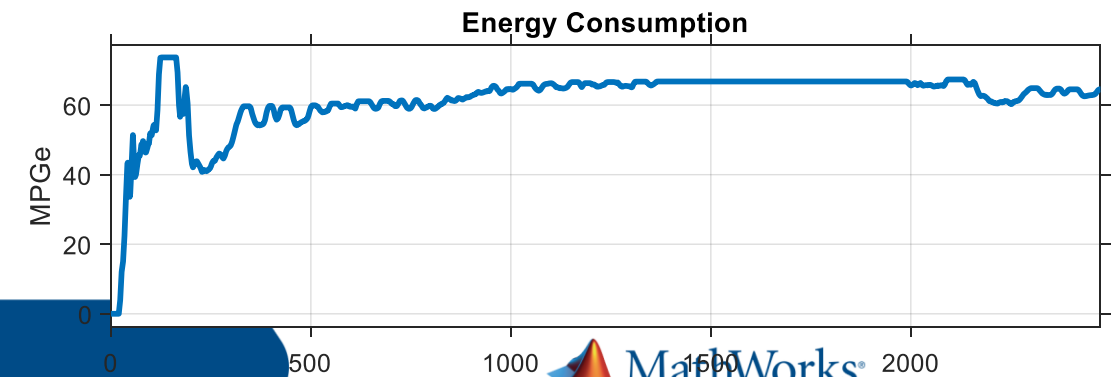








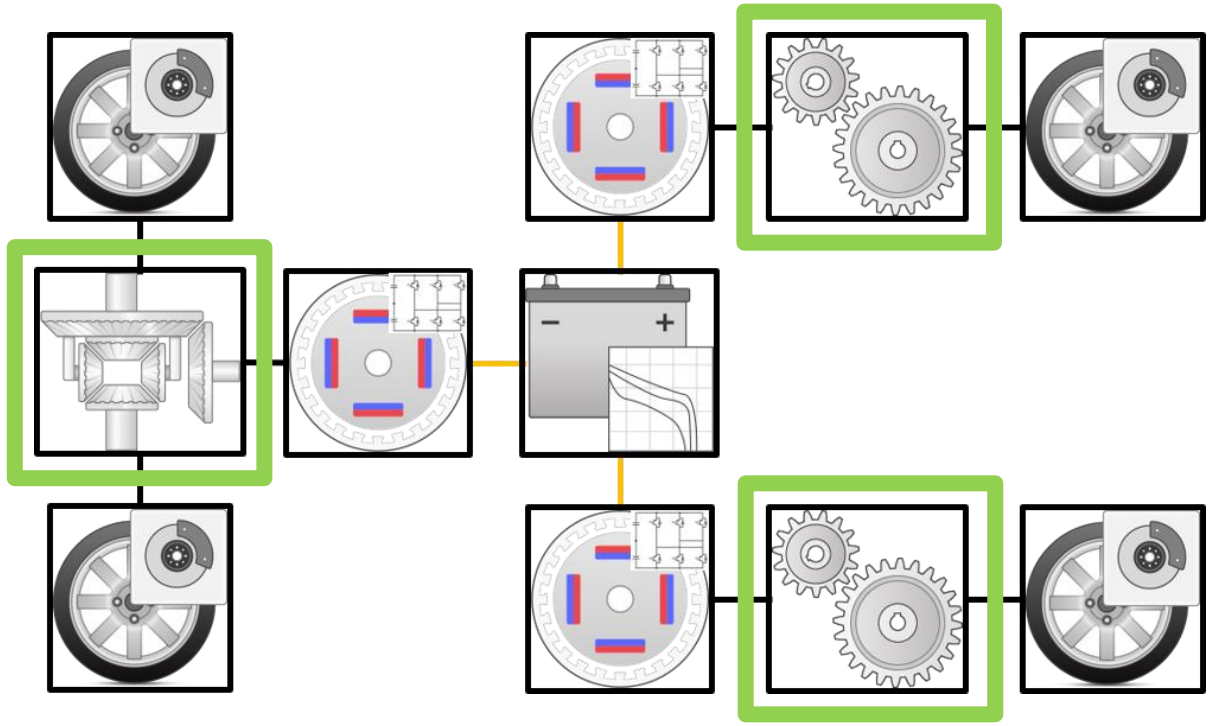




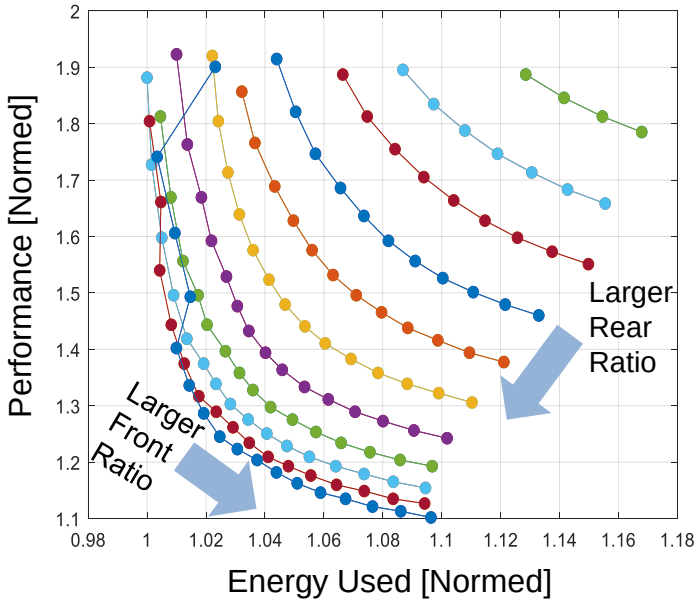
2. 优化前后轴的传动比

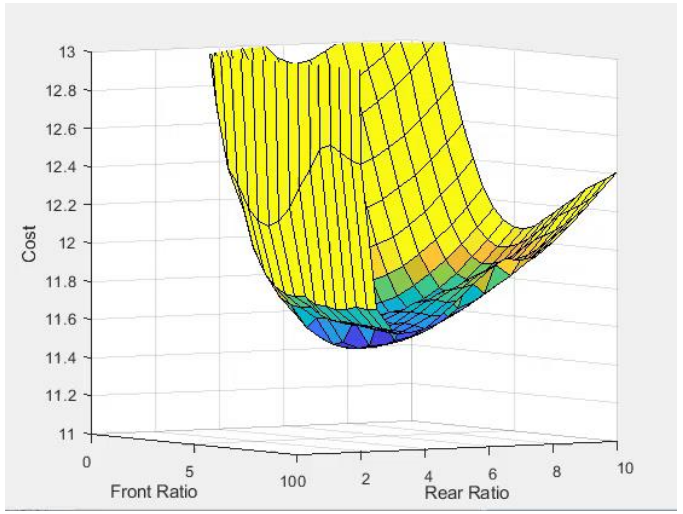
- 重用模型/EMS控制，支持调整各个部件参数的仿真

- 是否可以优化传动比?
  - 将多个驾驶循环的能耗降至最低
  - 优化车辆加速性能

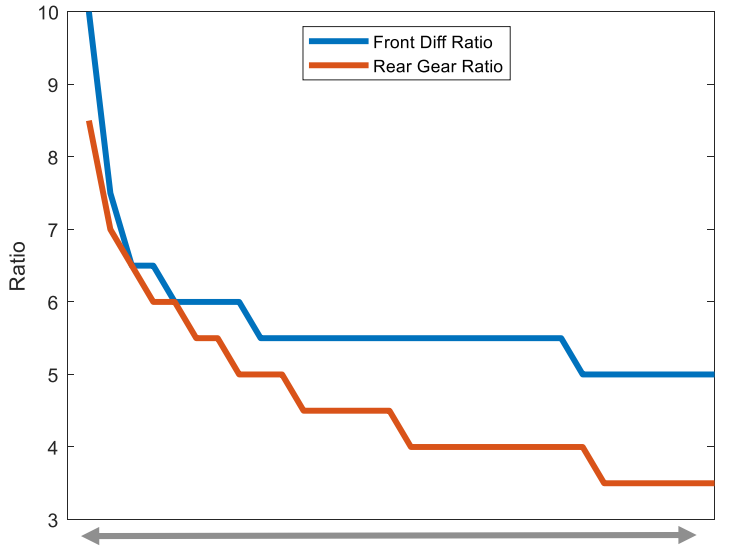


2.优化前后轴的传动比





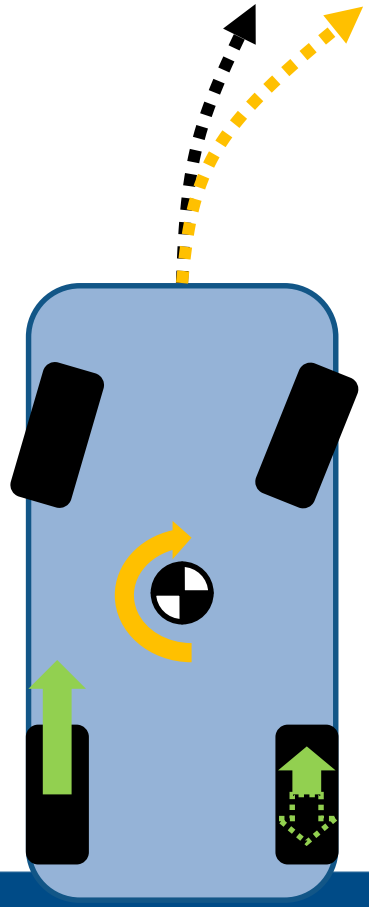
$$\min_{N_f,N_r} (0.55E_{FTP} + 0.45E_{HWY})\, W_1 + W_2(T_{0-120KPH})$$

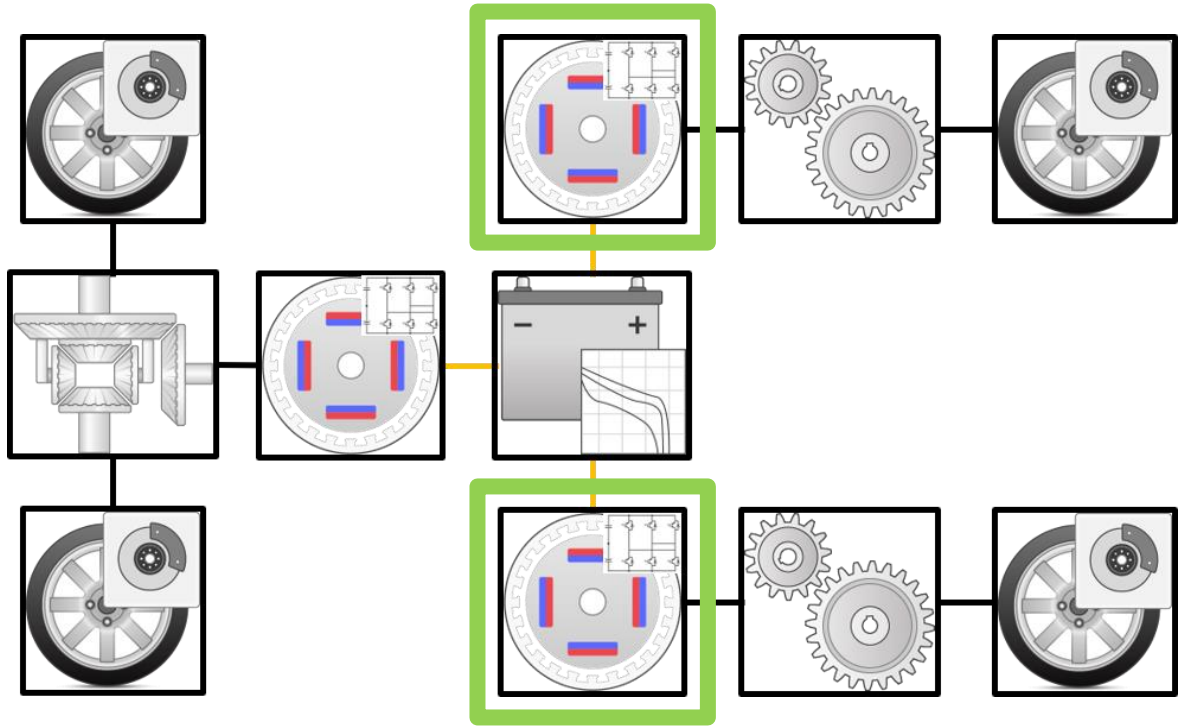


- 能量消耗与加速性能之间存在帕累托曲线
- 成本函数可以用于帮助确定最佳传动比
- 系统效率的权重越高，优化的传动比越低

3. 轮毂电机扭矩分配

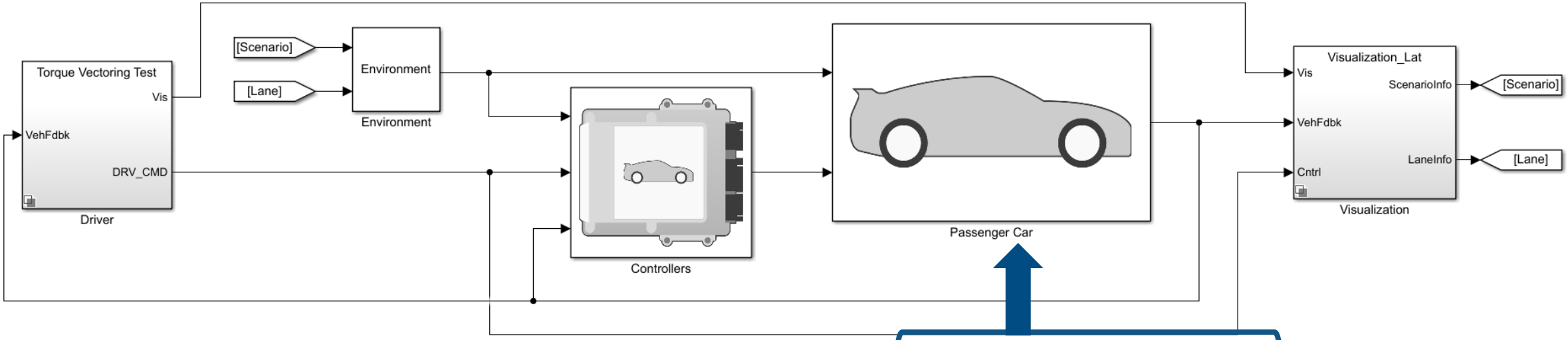
- 双后轮电机





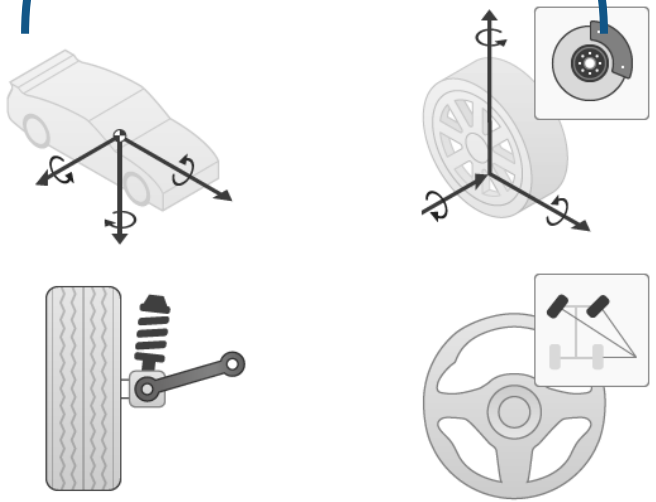
- 评估扭矩分配 (Torque Vectoring):
  - 详细的传动系统+ 横向车辆动力学模型
  - 扭矩控制策略可以与能量管理策略兼容
  - 确定改进目标

车辆动力学模型



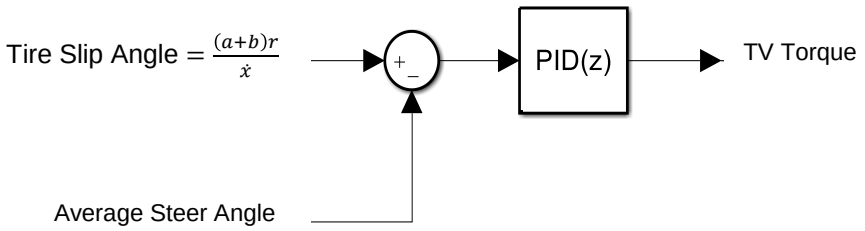
- 在车辆模型上添加可变子系统:
  - 6 DOF 车辆模型
  - 2 DOF 轮胎+制动模型
  - 悬架
  - 转向

14-DOF



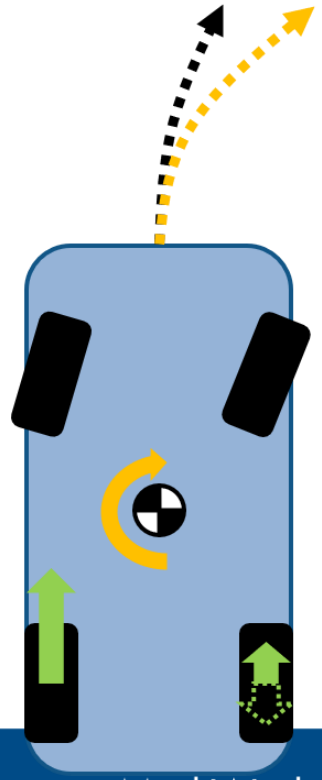
- 沿用详细的传动控制和能量管理控制

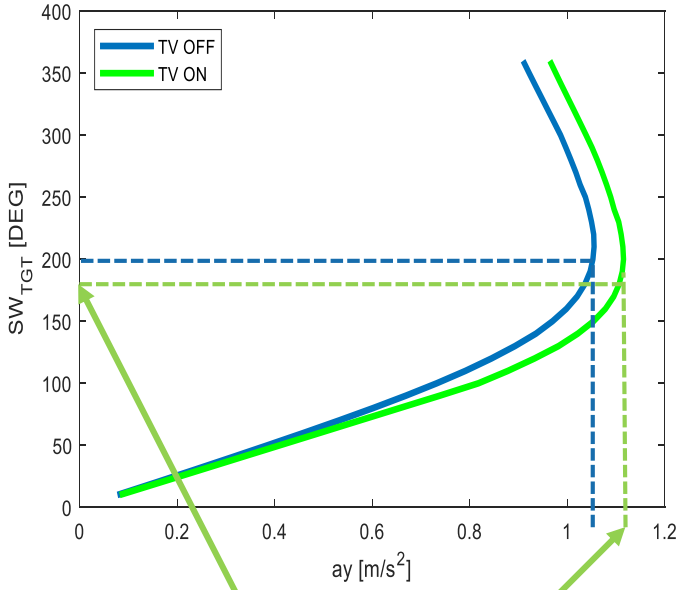
车身动态控制 – 轮毂电机扭矩分配



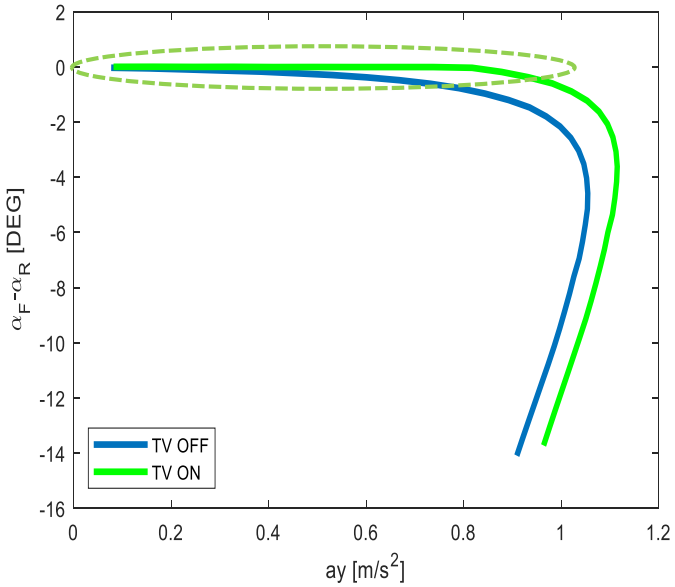
A Torque Vectoring Strategy for Improving the Performance of a Rear Wheel Drive Electric Vehicle

Jyotishman Ghosh, Andrea Tonoli, Nicola Amati
Department of Mechanical and Aerospace Engineering
Politecnico di Torino
Turin, Italy
Email: jyotishman.ghosh@polito.it





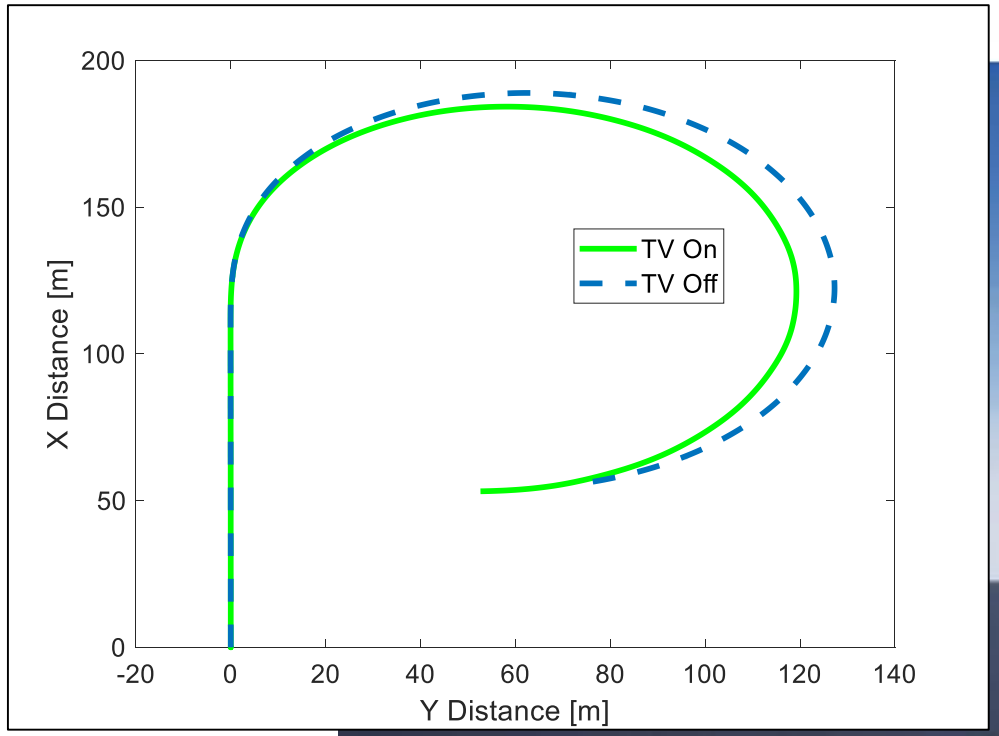
横向加速度更大，而转向输入减少8.7%



更长的轮胎线性滑移角区域，而横向加速度增加了5.7%

MathWorks

车身动态控制 – 轮毂电机扭矩分配

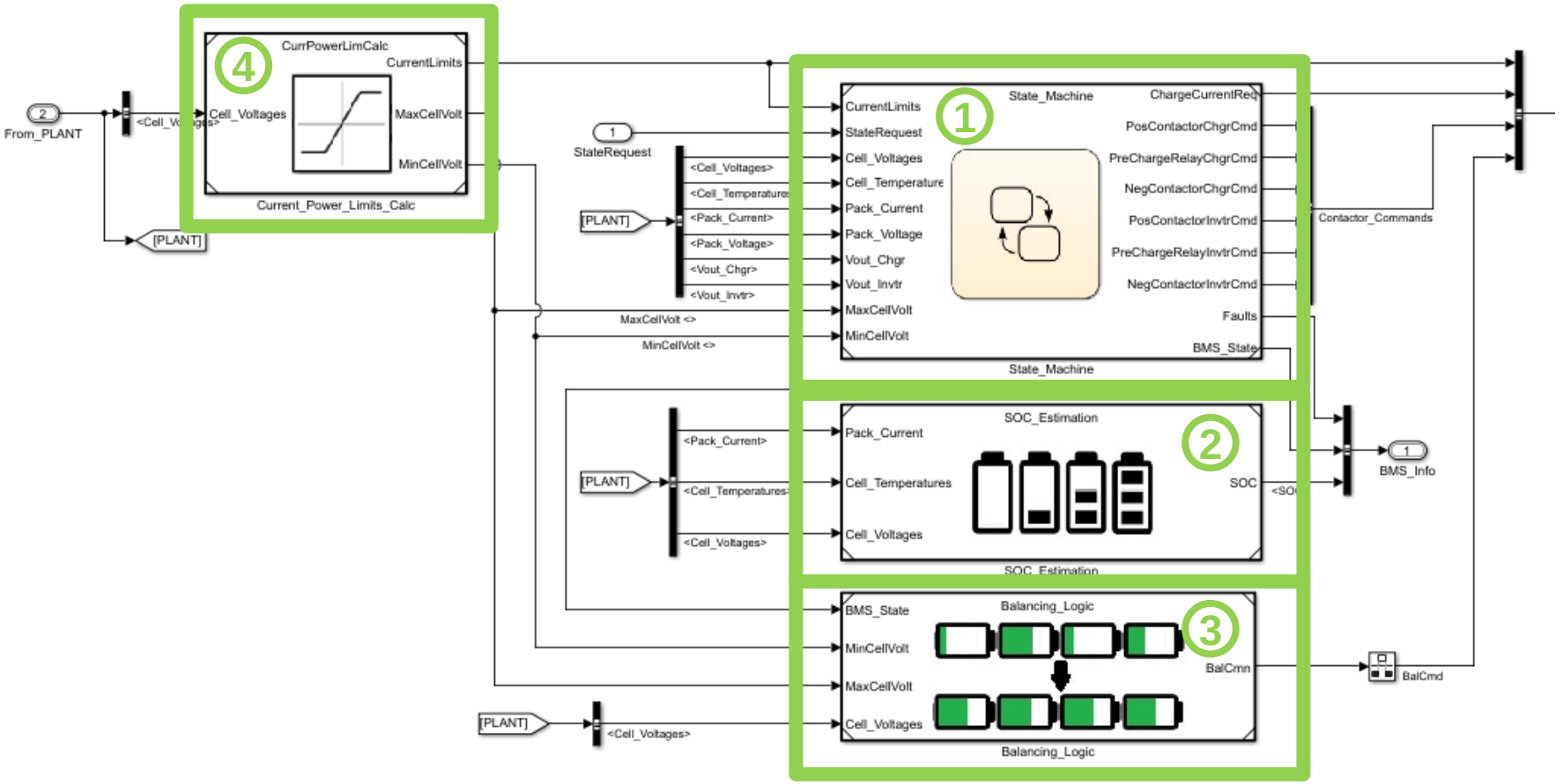


4. 集成详细的电池管理系统（BMS） / 电池

- 电池领域专家开发的详细的电池管理系统（BMS） / 电池模型
- 使用 Git “子模块” 把BMS项目添加引用到整车simulink project中
- 使用可变子系统集成BMS控制器和详细的电池

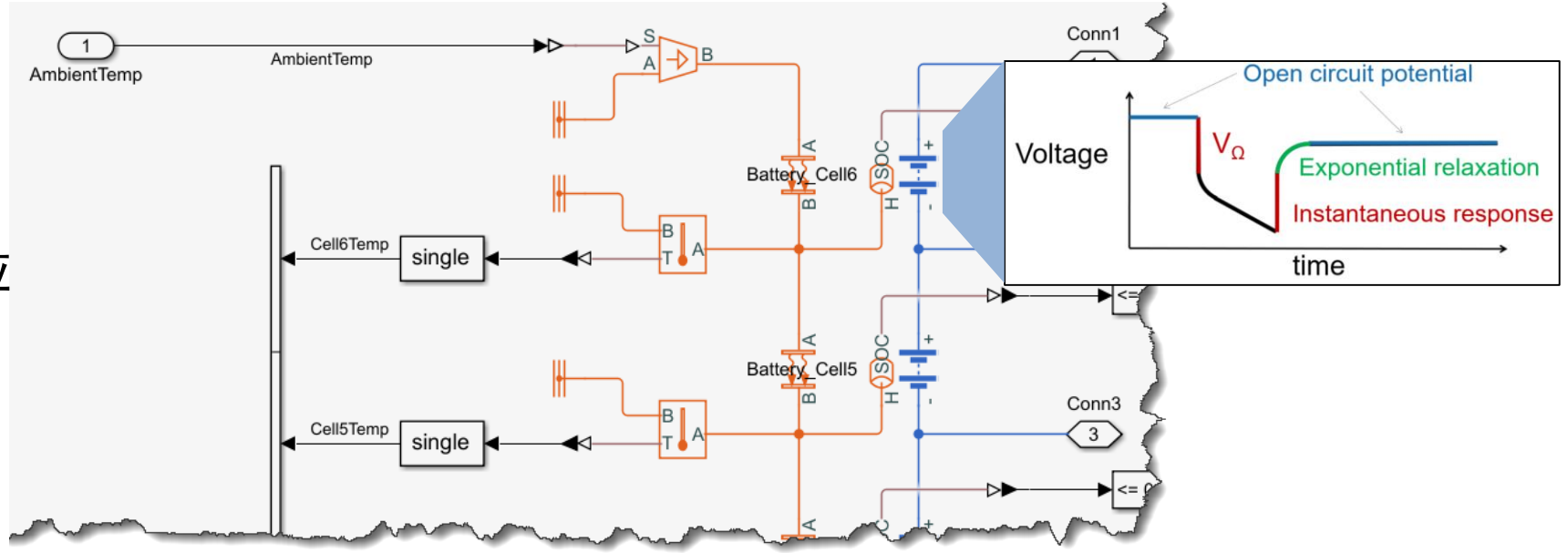
电池管理系统（BMS） 子系统

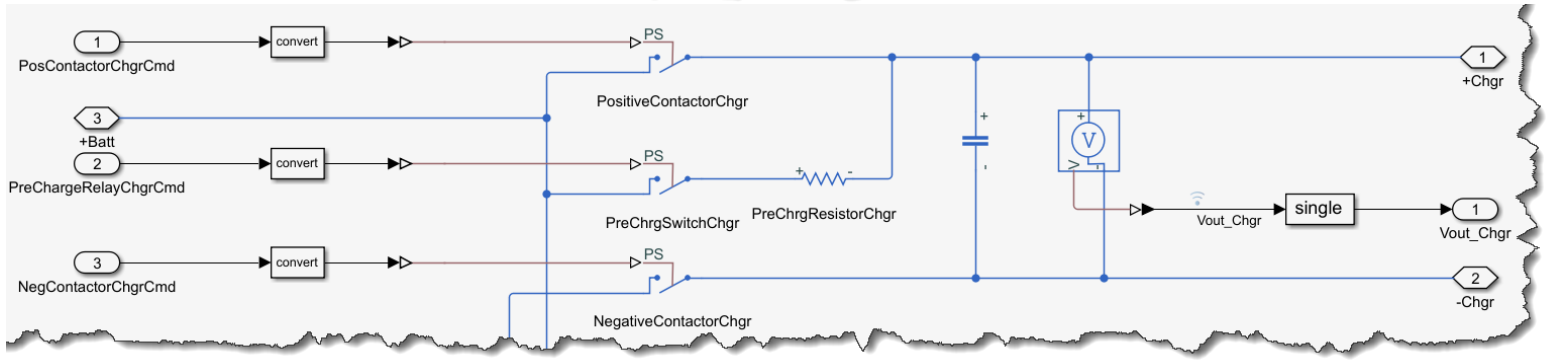
1. 状态机
   - BMS 状态
   - 故障检测
   - 接触器管理
2. SOC 估计
   - 无迹卡尔曼滤波UKF / 扩展卡尔曼滤波EKF
3. 电池平衡逻辑
4. 限流计算

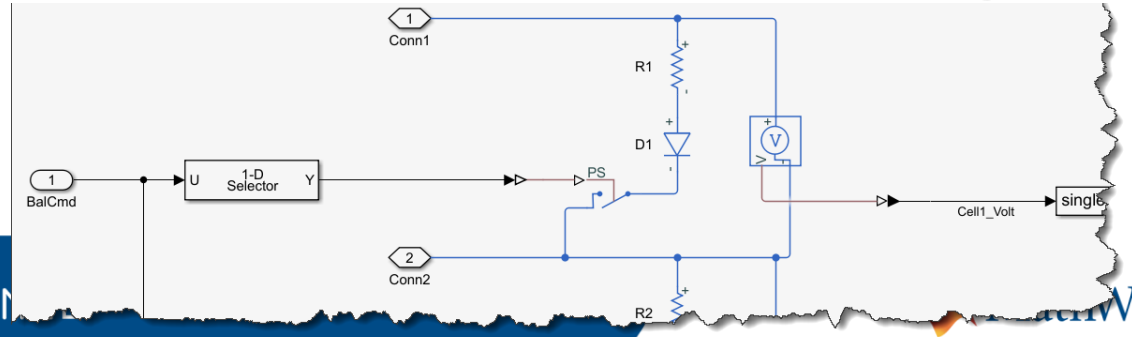


详细电池模型

- Simscape
  - RC 等效电路的动态响应
  - 热效应
- 接触器
  - 逆变器
  - 充电器
- 电池平衡

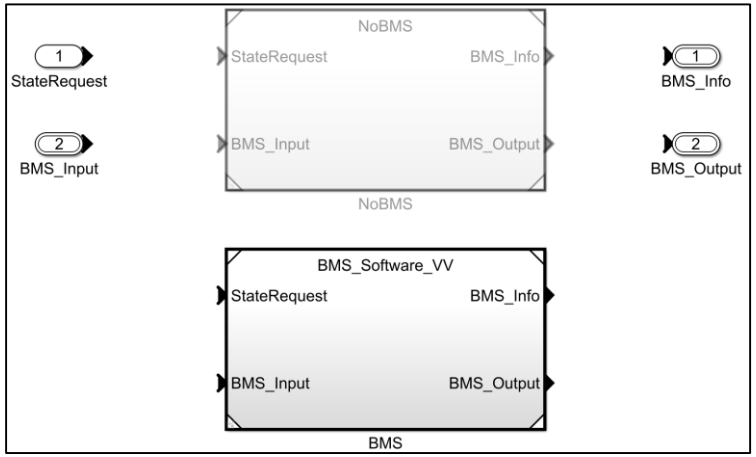


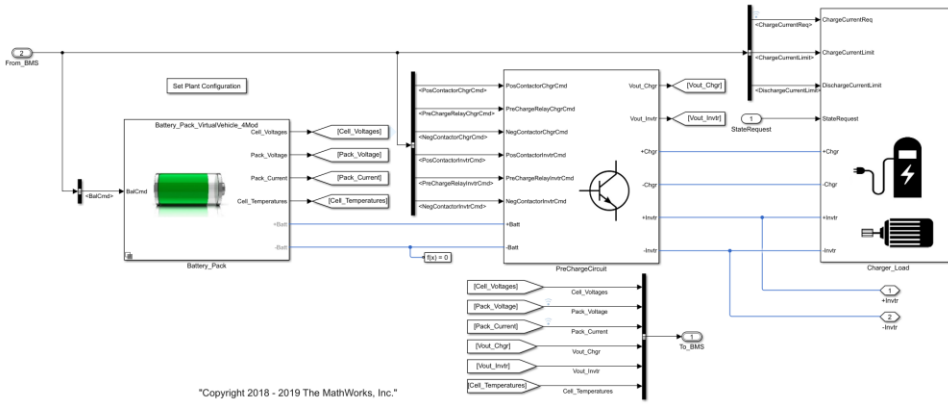




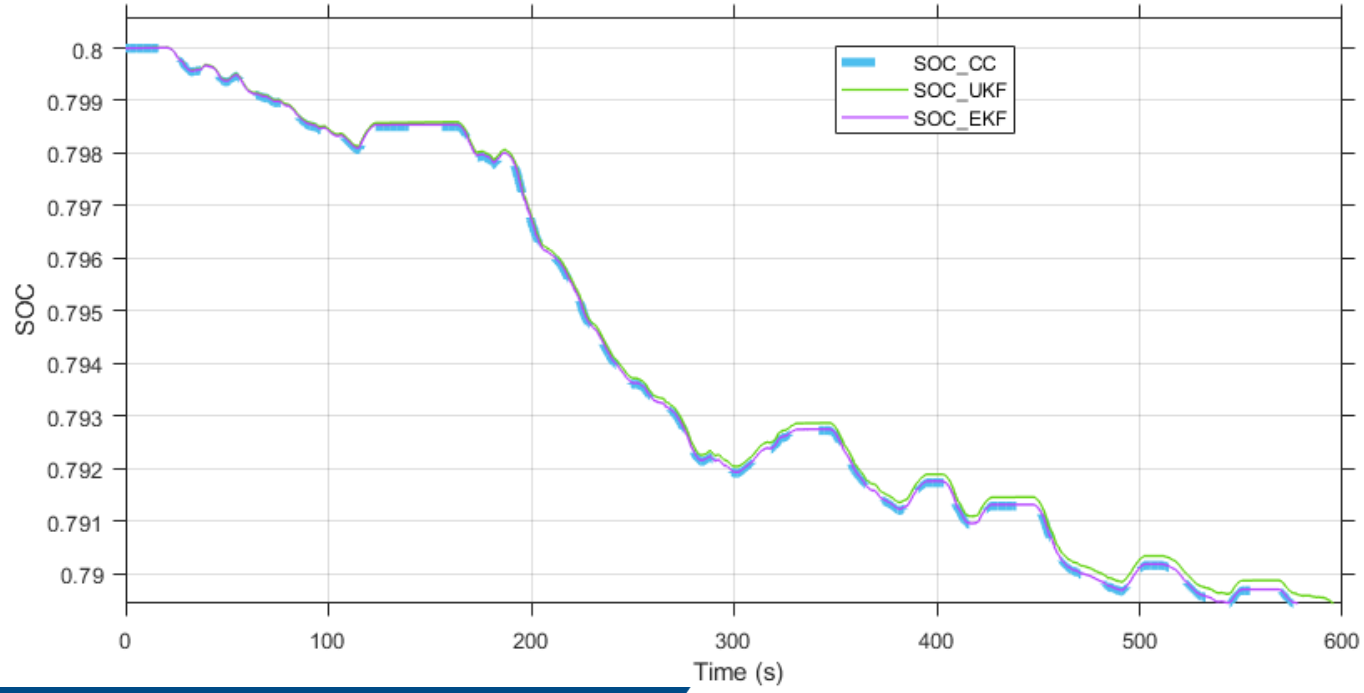
BMS / 电池集成与结果

- 集成
  - BMS 模型引用
    - 重用BUS对象
  - 电池变体
  - 将参数添加到数据字典（Data Dictionary）





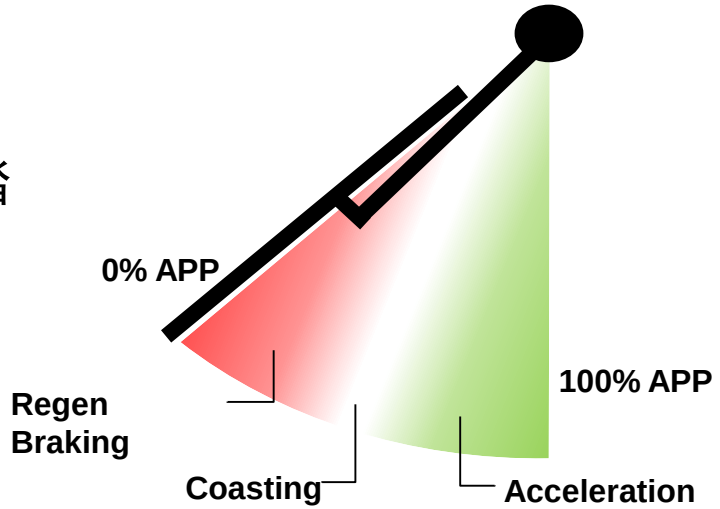
- 结果
  - 直接集成
  - 使用整车模型测试BMS / 电池

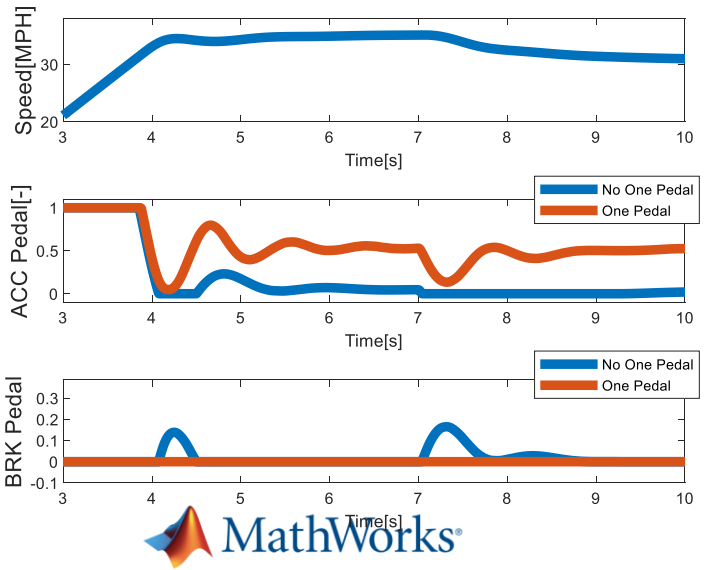


5. 驾驶员在环功能

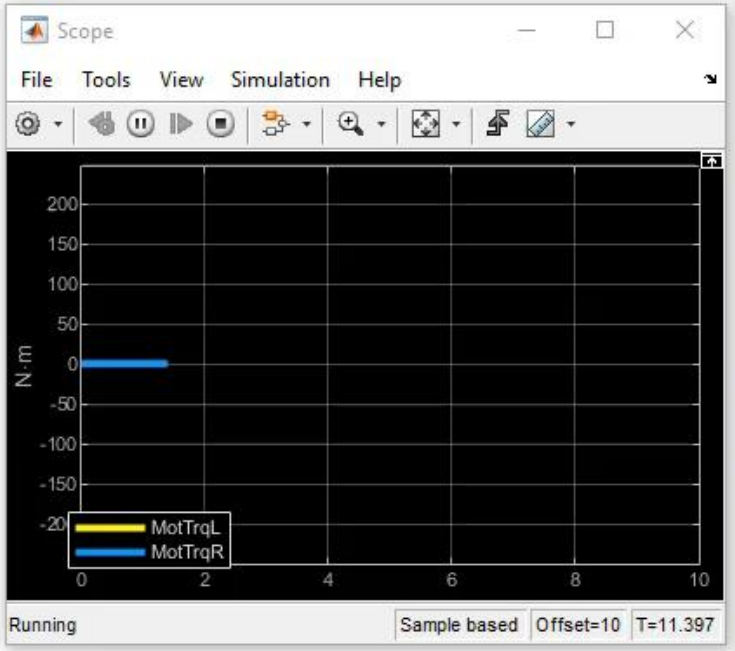
- 通过驾驶员在环功能增强车辆模型
  - 驾驶模拟器功能
    - Logitech G29 方向盘/ 踏板
    - Unreal Engine 显示
  - 控制算法的开环测试

- 单踏板驱动算法
  - 将原先油门踏板信号映射到单踏板对应的信息上
  - 区间标定影响驾驶性与“驾驶乐趣”特性





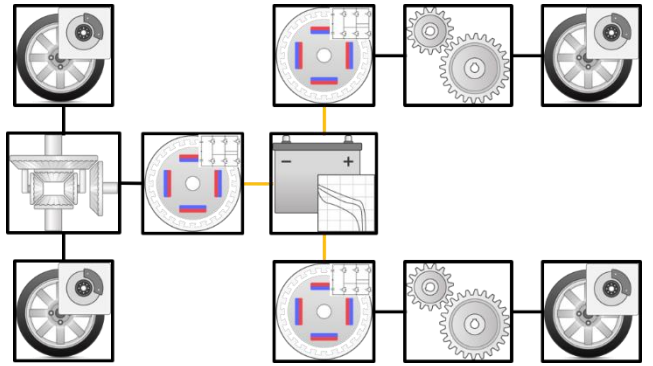
驾驶员在环功能

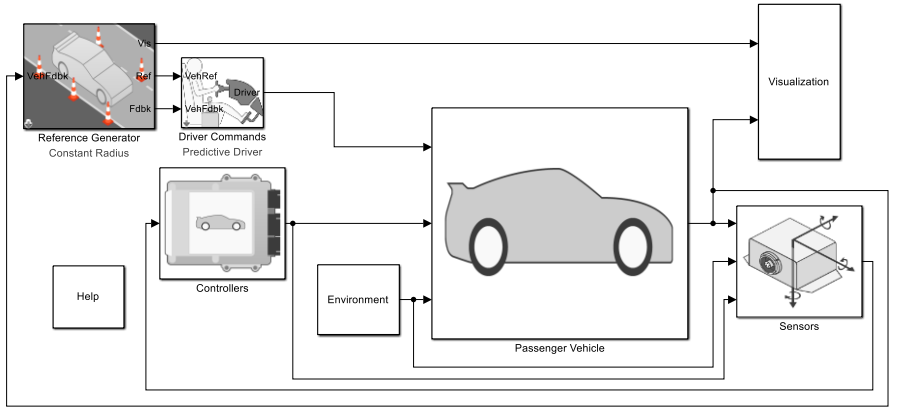

Scope
File Tools View Simulation Help
200
150
100
50
0
-50
-100
-150
-200
N·m
MotTrqL
MotTrqR
0 2 4 6 8 10
Running
Sample based
Offset=10
T=11.397

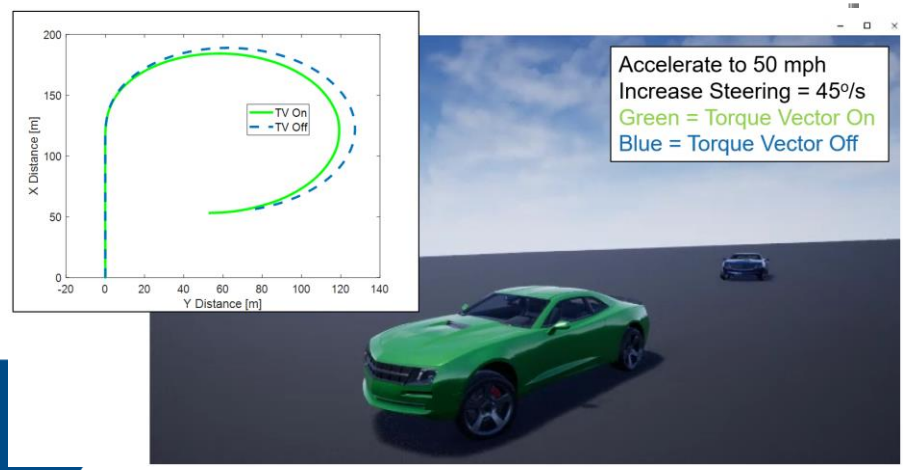

AutoVrtlEnv (64-bit, PCD3D_SM5)

总结

- MathWorks 在虚拟车辆仿真上的应用:
  - 使用Powertrain Blockset 和 Vehicle Dynamics Blockset快速评估电气化动力总成
  - 参考应用提供了模型构架和测试用例的模板
  - 单个模型用于支持多种基于模型设计的活动







Q & A

如果您对所介绍的材料感兴趣，请与我们联系