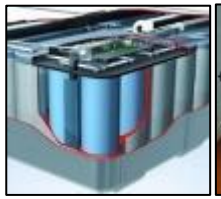
Model Based Design approach for E-Drive development using MATHWORKS






ABOUT THE GROUP

Established in
1938

Over **500** people in R&D, Engineering

Over **15,000** members

Over **50** factories spread over India

Collaborations with **Global** members

Several **firsts** in introduction of new technologies & processes

Diversified Verticals
OEM, Parts, Plantations, Retail

Multi-location **state-of-the-art** R&D Centres

Distribution Centres
across the country

$2.5b
Group Turnover

$250m
Component Division Turnover

ABOUT THE GROUP

Total Companies

MANUFACTURING - 18	TRADE & DISTRIBUTION - 11	PLANTATIONS - 3	SERVICES - 6

1940s	**Simpsons & Co Limited (founded 1840)** Diesel Engines **India Pistons Limited** Pistons, Pins, Rings & Liners **Addison & Co Limited (founded 1873)** Cutting Tools, M/C Tool Accessories
1950s	**Bimetal Bearings Limited** Thinwall Bearings **Amalgamations Repco Limited** Clutch Parts, Flywheel Ring Gear (IP Repco) **Shardlow India Limited** Crankshaft & Forging **AMCO Batteries Limited** Lead Acid Batteries
1960s	**Tractors & Farm Equipment Ltd (TAFE)** Tractors
1990s	**IP Rings Limited** Steel Piston Rings, Orbital Forming, Crank Pins & Special M/Cing Tools (NPR, Japan) **Amalgamations Valeo Clutch Ltd** Clutch Assemblies (Valeo, France)
2010s	**BBL Daido** Automotive Engine Bearings (Daido, Japan)

Services & Retail

Distribution Services

George Oaks Ltd.

Speed-a-way

TAFE Access

Higginbothams

Plantations & Retail

T.Stanes & Co.

United Nilgiris Tea

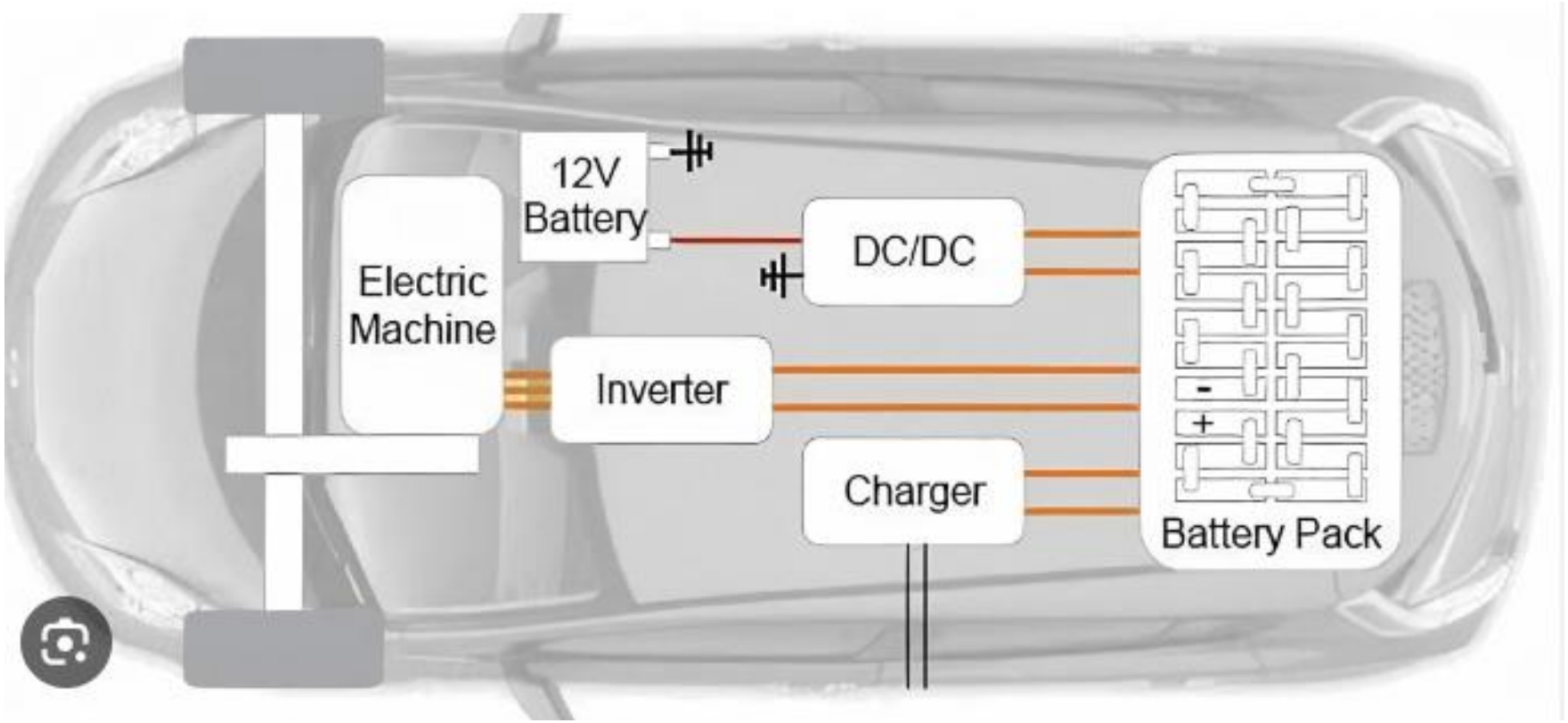
Logistics

SRVS

Corporate

Madras Advertising Co

Typical EV architecture



Courtesy: E-Vehicle Info

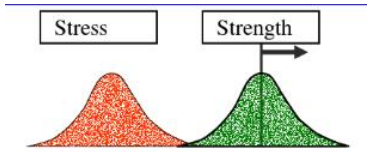
Design Metrics

Form & Fit

Function

Sustainability

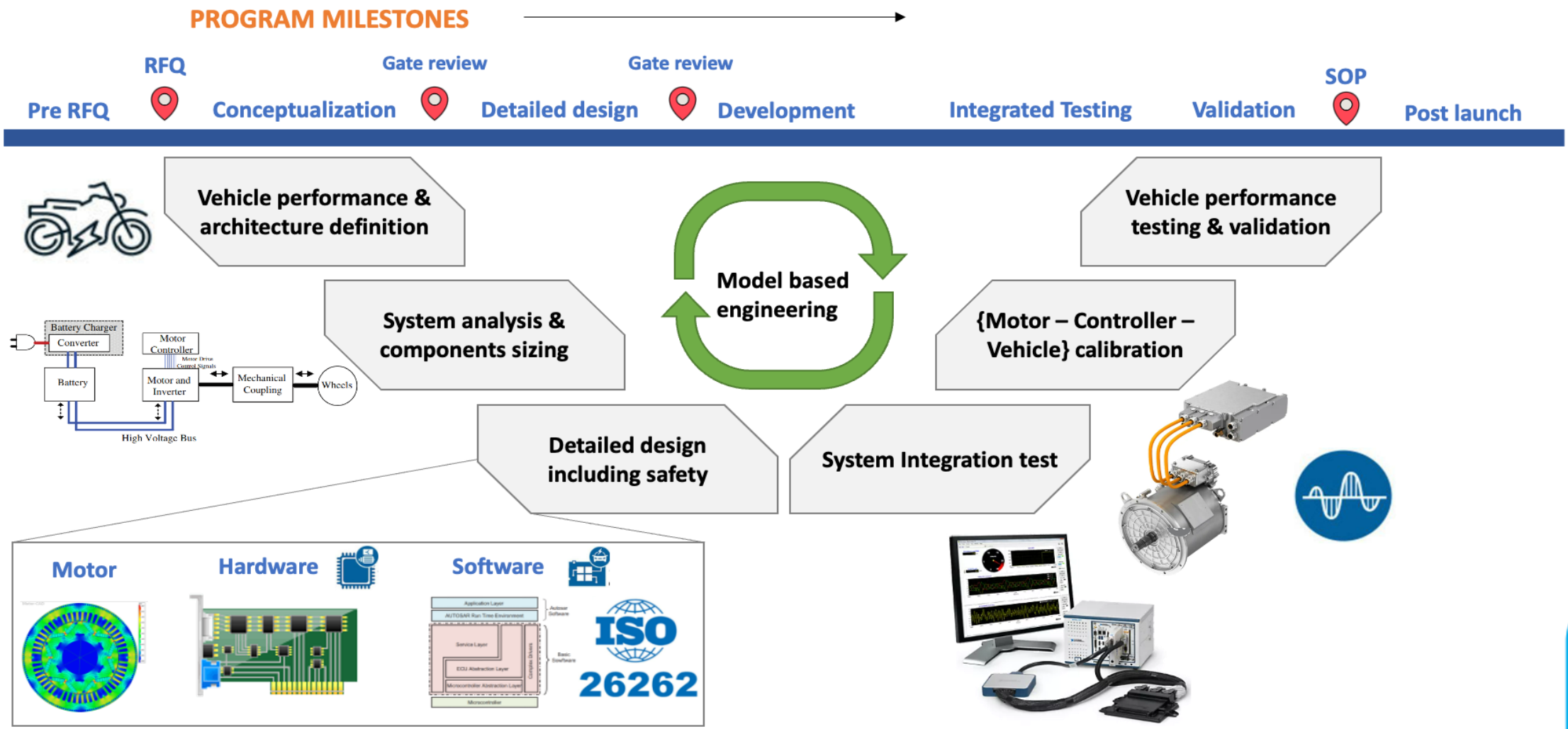
Safety & Compliance



Durability & Reliability

ISO 26262
Road Vehicles - Fuctional Safety

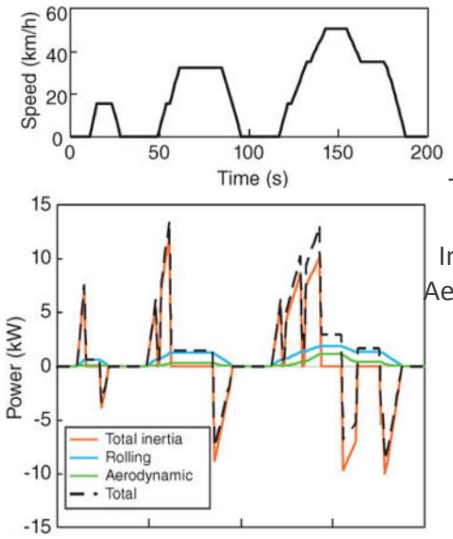
Product development Approach



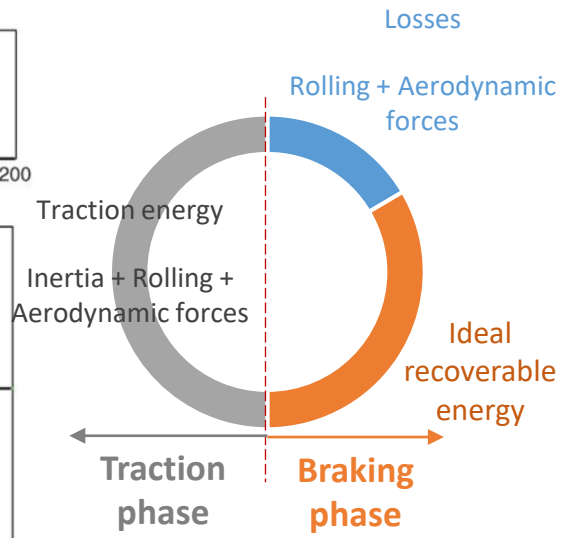
The “Why ?”

Model Based design

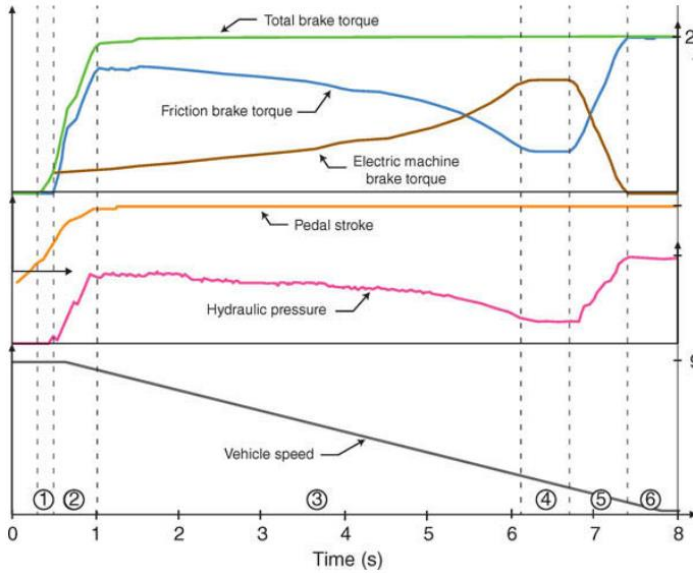
Drive cycle-based simulation



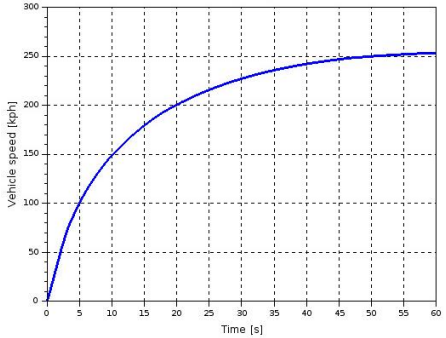
Energy balance study



Regen braking optimization

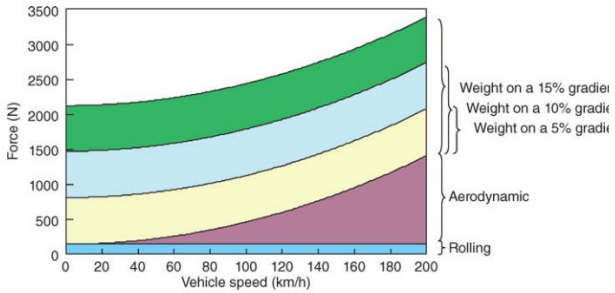


Vehicle acceleration performance

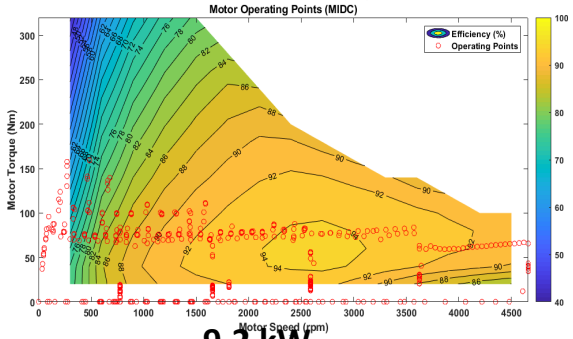


Range prediction for each drive cycle

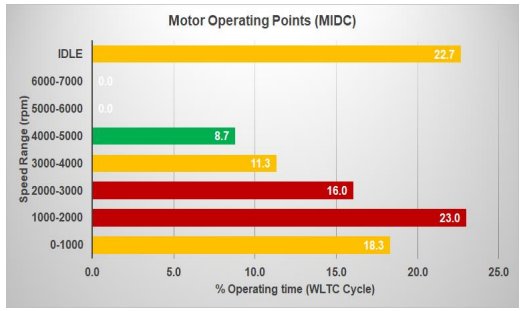
Road load forces



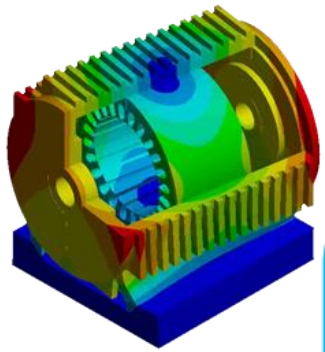
Motor operating points



Motor operating points



Motor thermal analysis



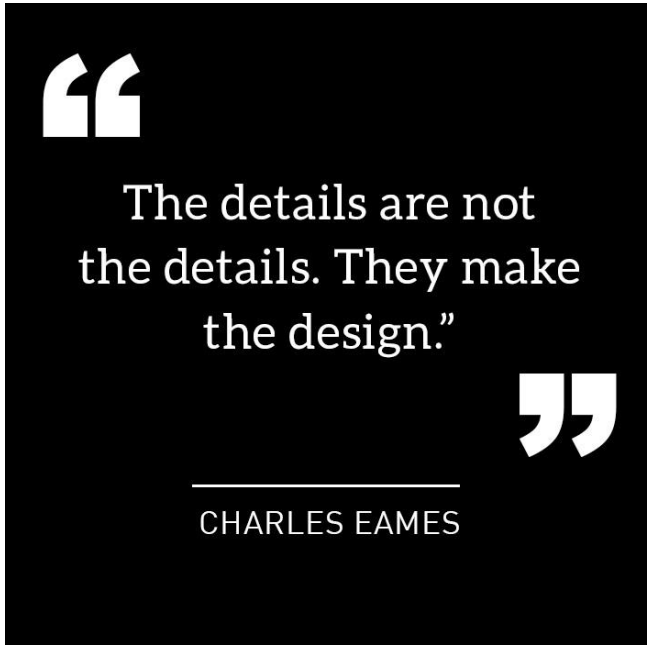
10 kW → **Battery** → **9.6 kW** → **Inverter** → **9.2 kW** → **Motor** → **8.2 kW** → **Drivetrain** → **7.8 kW** → **Wheels**

η – 96% | η – 95% | η – 90% | η – 95%

POWERTRAIN SIZING

SIMPSONS

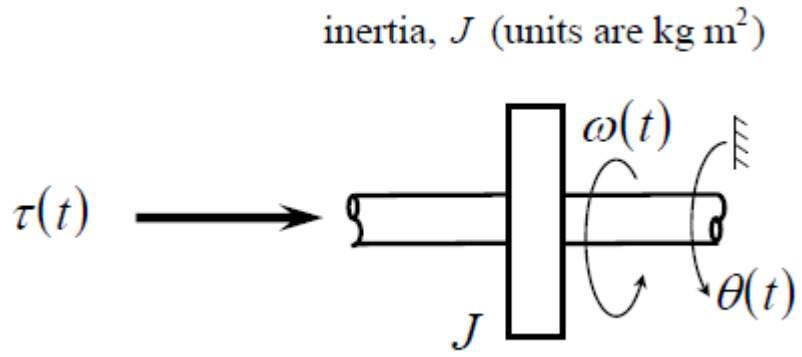
The “How” & The “Details”



MODELLING TECHNIQUES

ANALAGOUS MODELLING

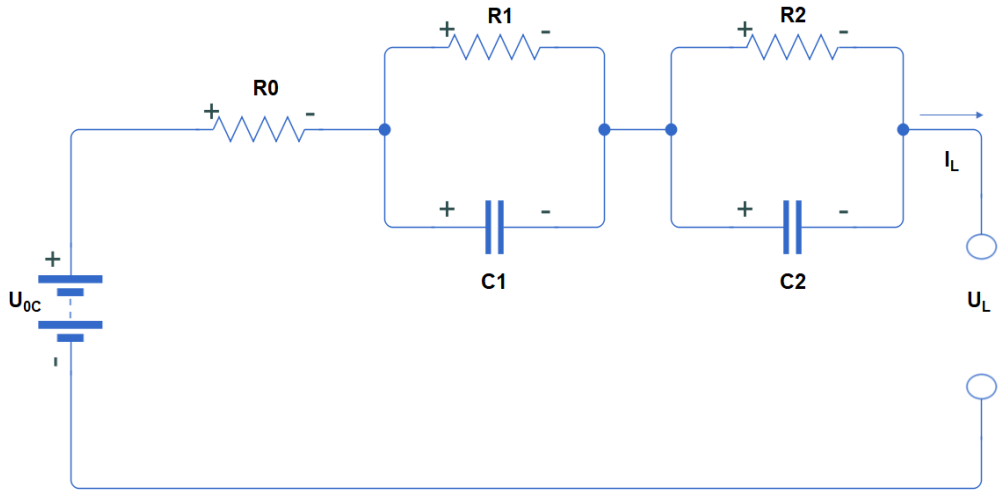
- Represent system by elemental equations



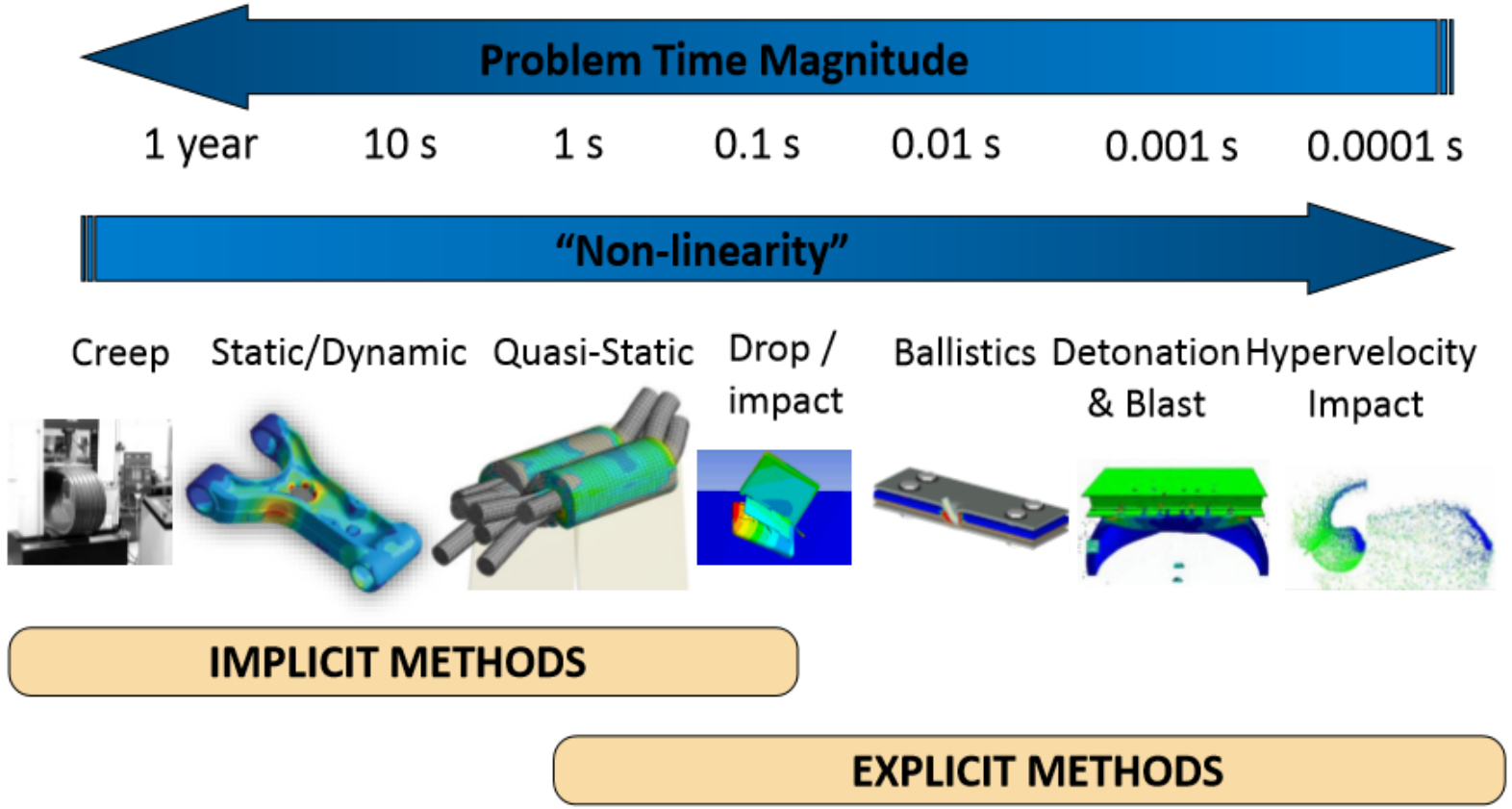
$$J\frac{d}{dt}\omega(t) = \tau(t)$$

ACAUSAL MODELS

- System represented and connected physically



MODELLING ALGORITHM (IMPLICIT/EXPLICIT)

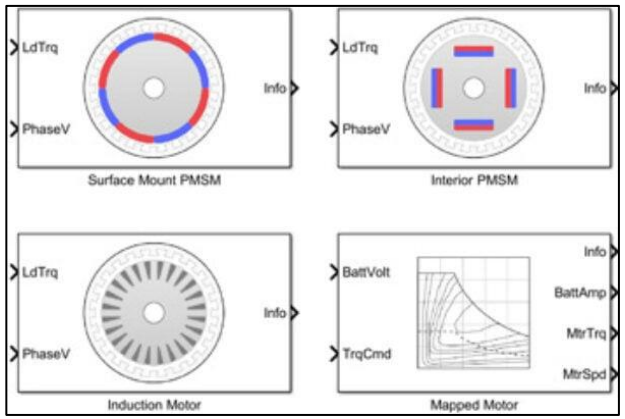


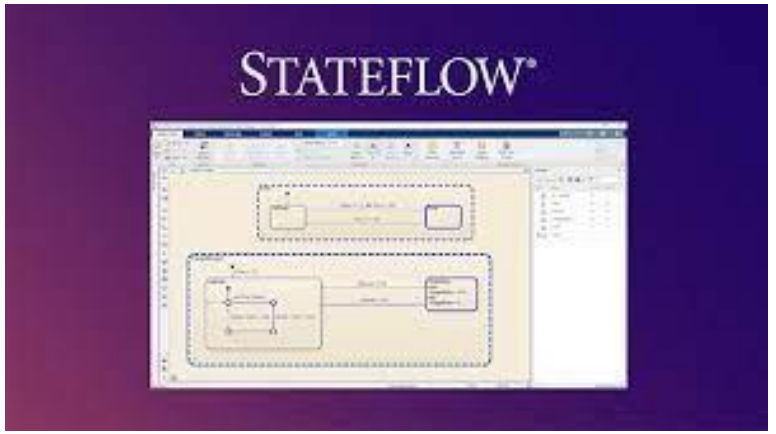
- Euler
- Runge Kutta
- Dormand Prince
- Backward Euler
- ODE 14x

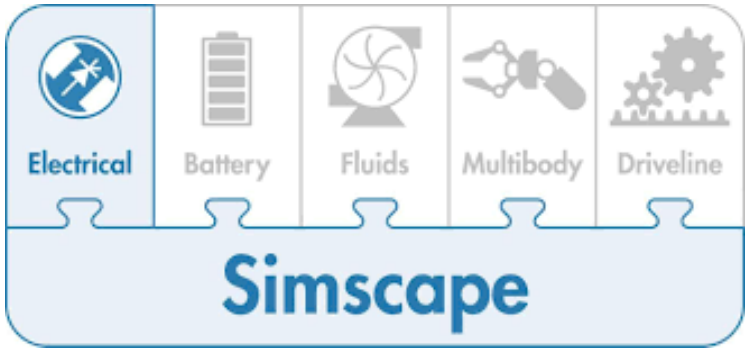
SIMPSONS

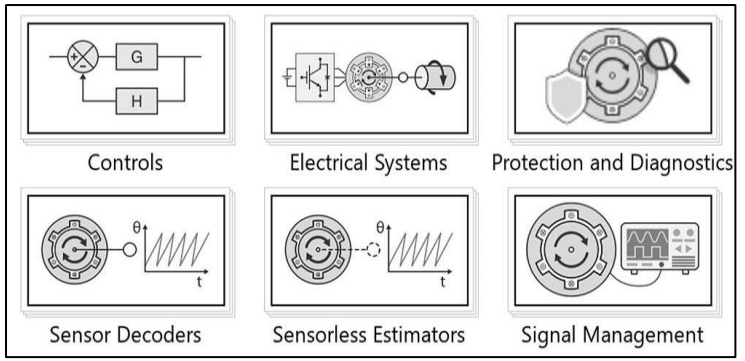
MATLAB & Simulink Blocksets

- MATLAB
- Simulink
- Powertrain block set
- Motor Control blockset
- Simspcape drive line
- Simscape Electrical
- Stateflow

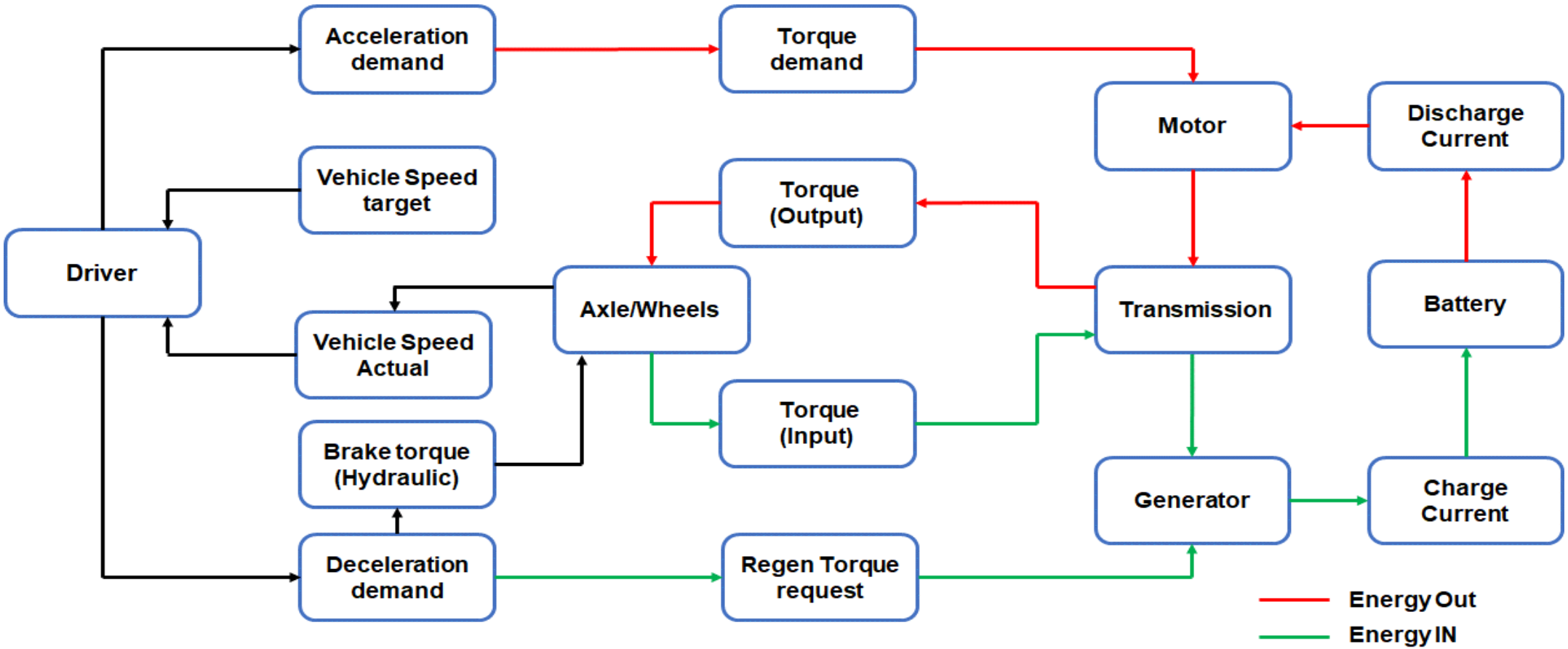








VEHICLE MODELLING APPROACH



SIMPSONS

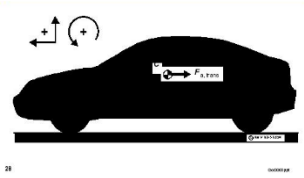
The “Story”

System Requirements

Road Loads

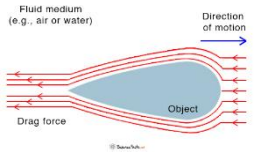
Gradient resistance

Inertia Resistance

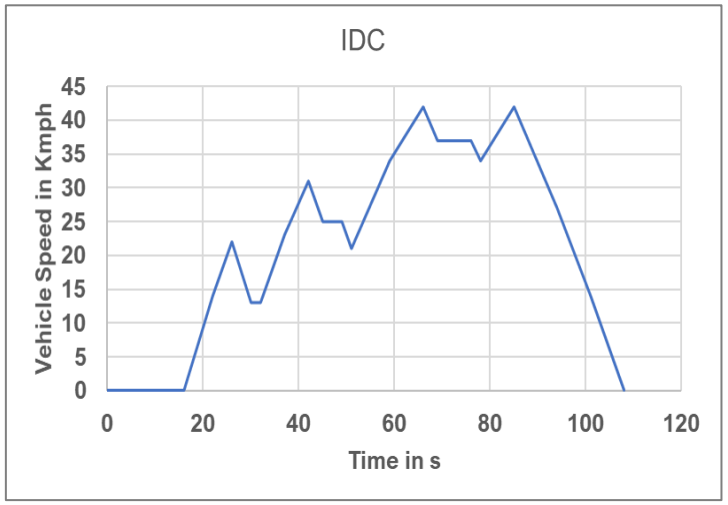


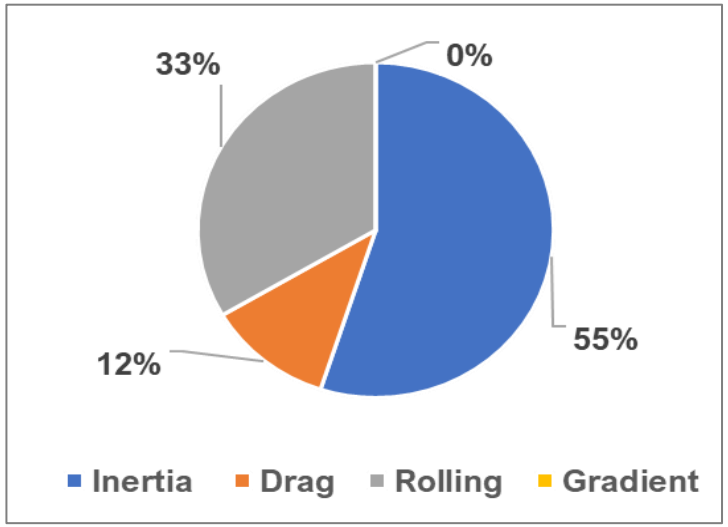
Rolling Resistance

Drag Resistance

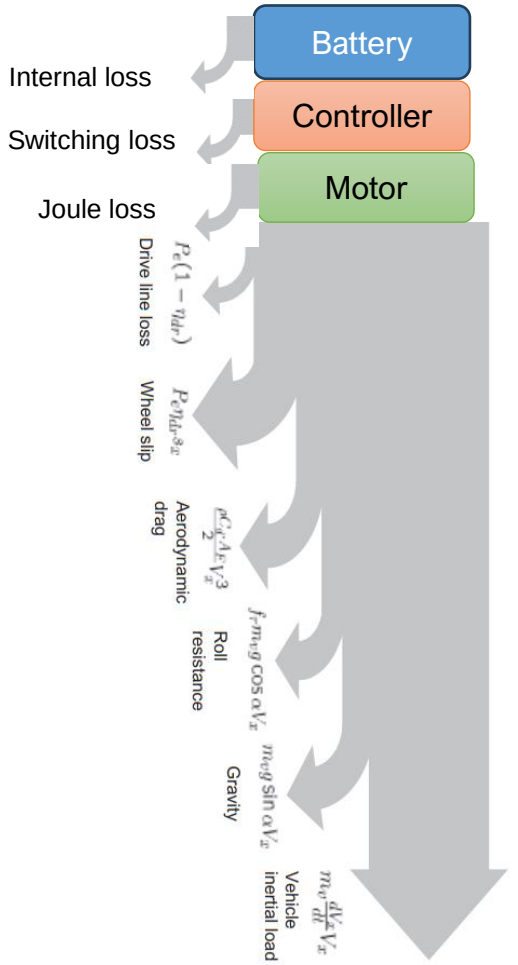


Drive Cycle Analysis





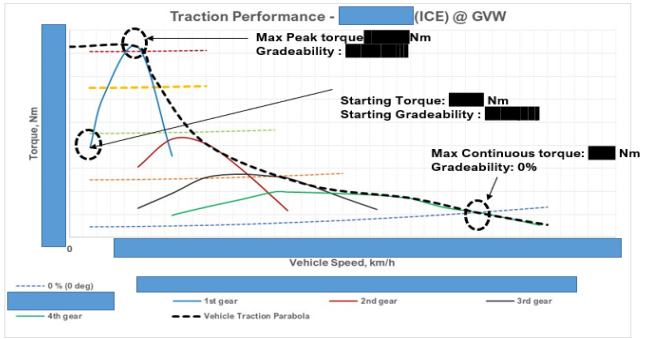
Road load impact on typical 3W @700 kg



Required output power to meet all driving requirements

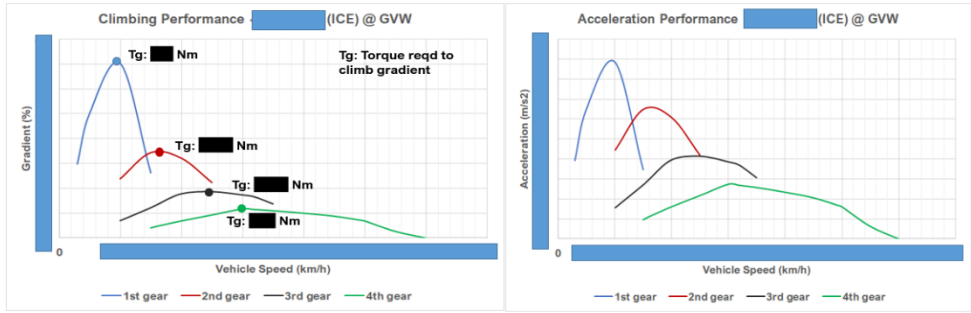
VEHICLE PERFORMANCE

VEHICLE TRACTION DIAGRAM (ICE)



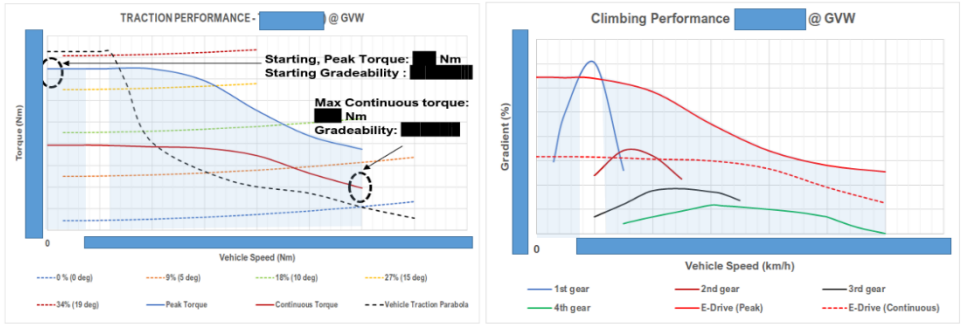
- With the derived ICE characteristics, the current vehicle can achieve a gradeability of [redacted] comfortably in first gear
- The vehicle is expected to have a starting gradeability of [redacted]
- The Vehicle achieves top speed of [redacted] km/h at 0 deg gradient in 4th gear.
- To achieve a gradeability of [redacted] the vehicle requires a torque of [redacted]
- The peak torque availability is limited between vehicle speeds of 10 and 12 km/h

VEHICLE TRACTION PERFORMANCE (ICE)



	GEAR 1	GEAR 2	GEAR 3	GEAR 4
MAXIMUM GRADABILITY	[redacted] @ 10 km/h	[redacted] @ 15 km/h	[redacted] @ 25 km/h	[redacted] @ 30 km/h
MAXIMUM ACCELERATION	[redacted] m/s2 @ 10 km/h	[redacted] m/s2 @ 15 km/h	[redacted] m/s2 @ 25 km/h	[redacted] m/s2 @ 30 km/h

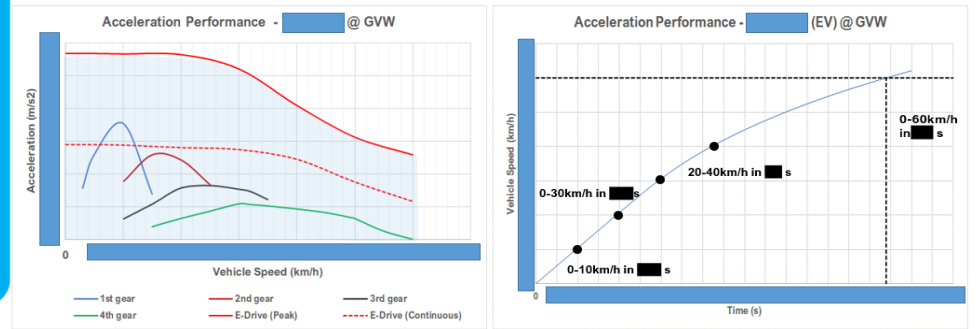
VEHICLE TRACTION DIAGRAM (E-DRIVE)



The shade represents operating points where e-drive has superior or equal torque than ICE drive train

Higher starting torque, flat torque region results in superior traction and climbing performance than ICE Drivetrain

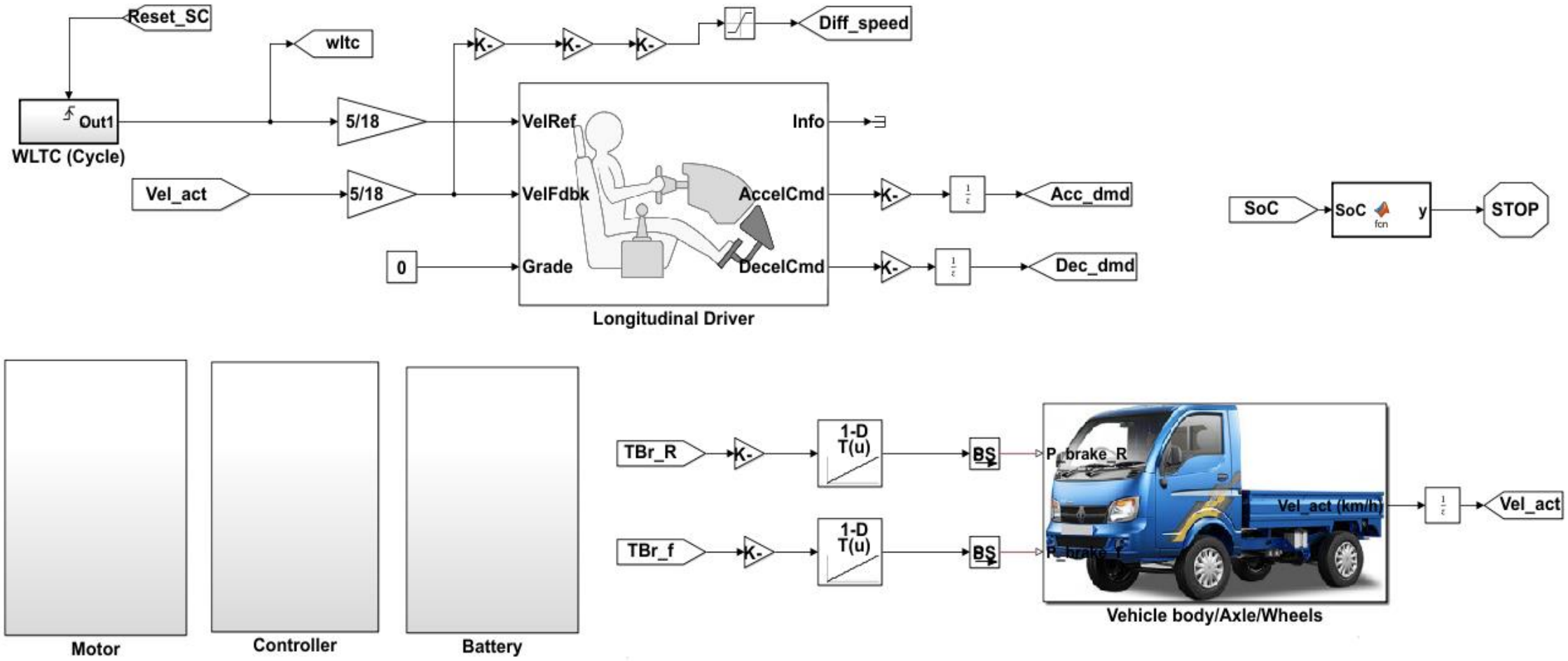
ACCELERATION PERFORMANCE - EDRIVE



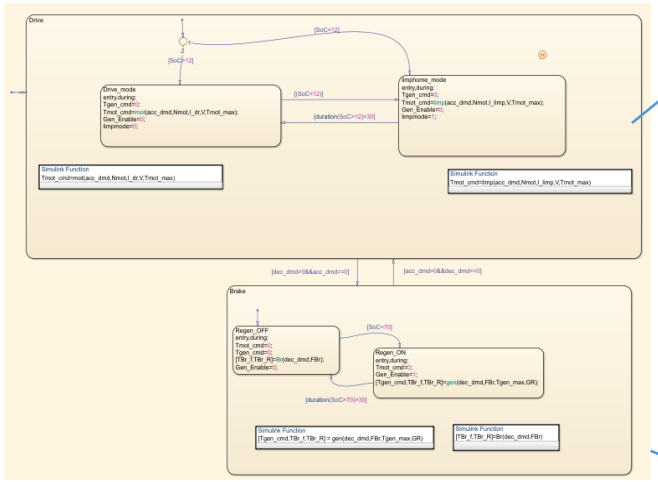
The shade represents operating points where e-drive has superior or equal torque than ICE drive train

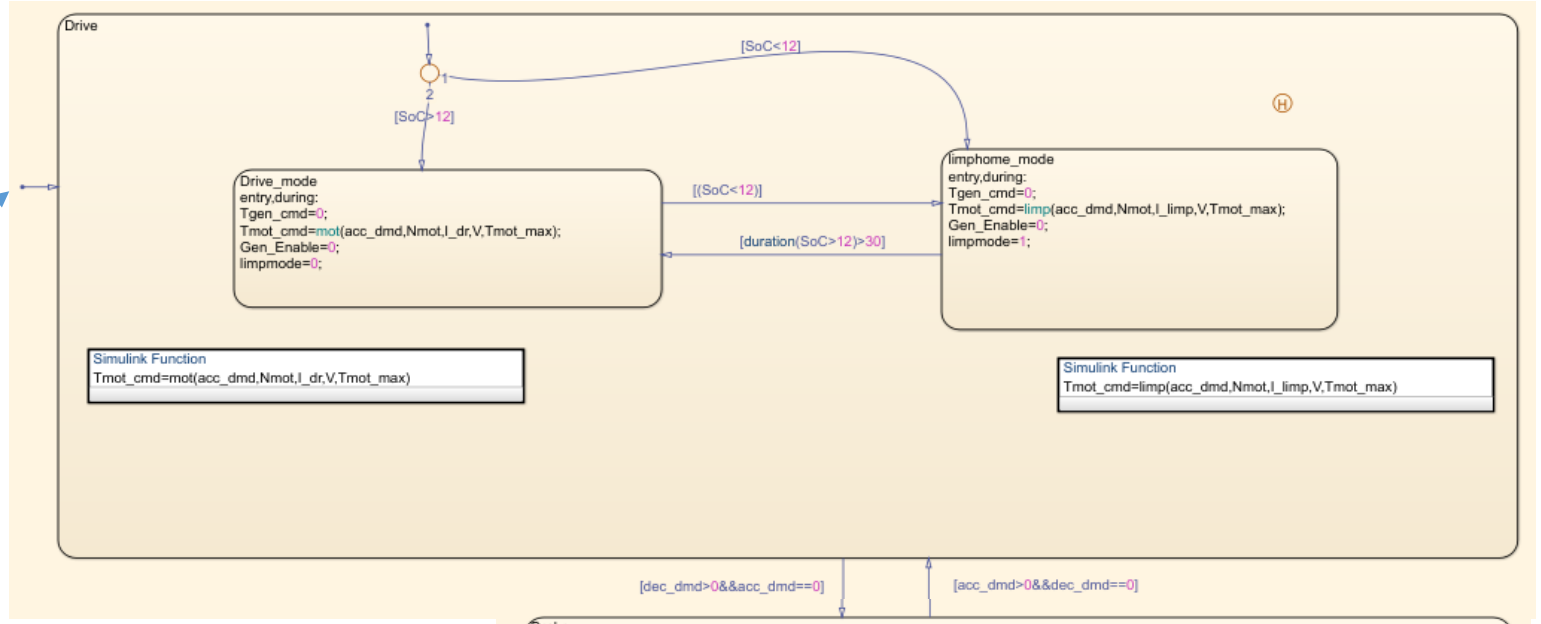
The E-drive acceleration performance exceeds the current ICE drivetrain

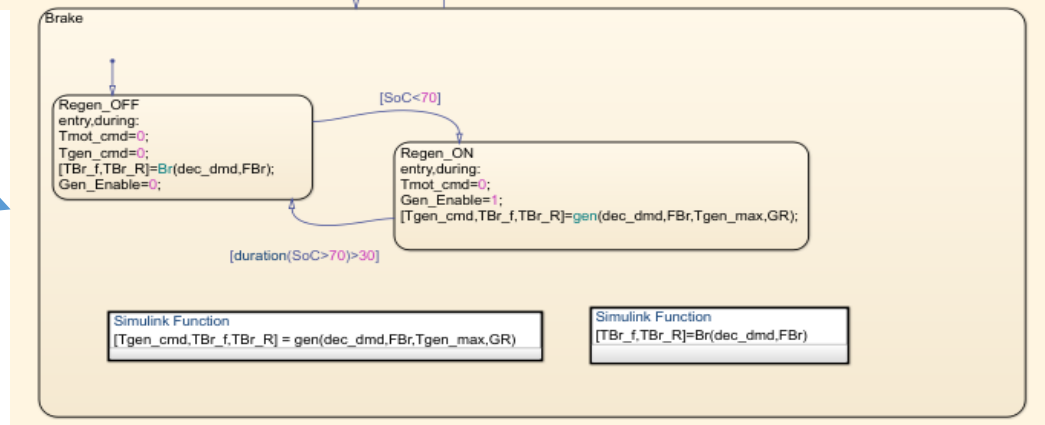
1D model – Simulink



1D model – Vehicle Supervisory Controller

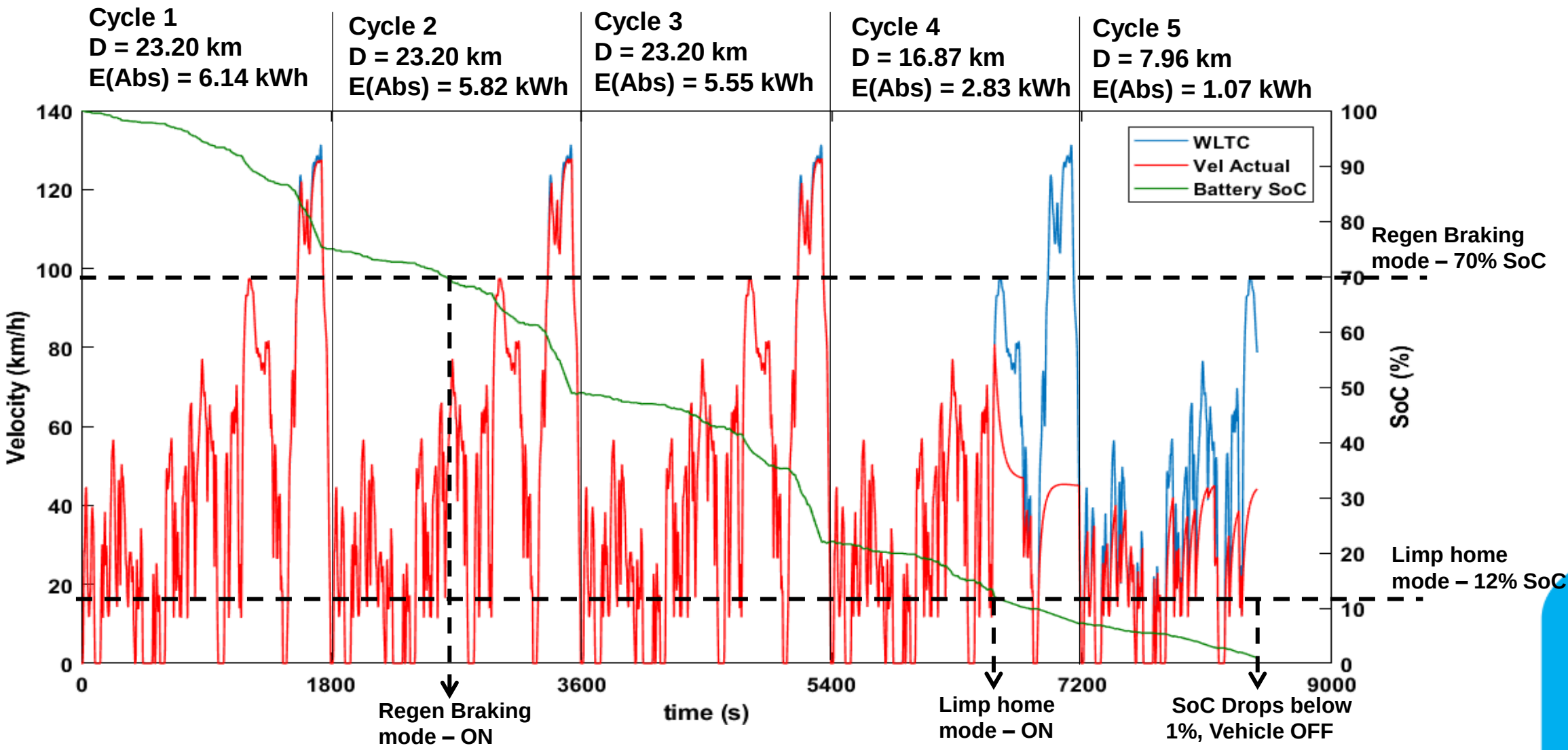






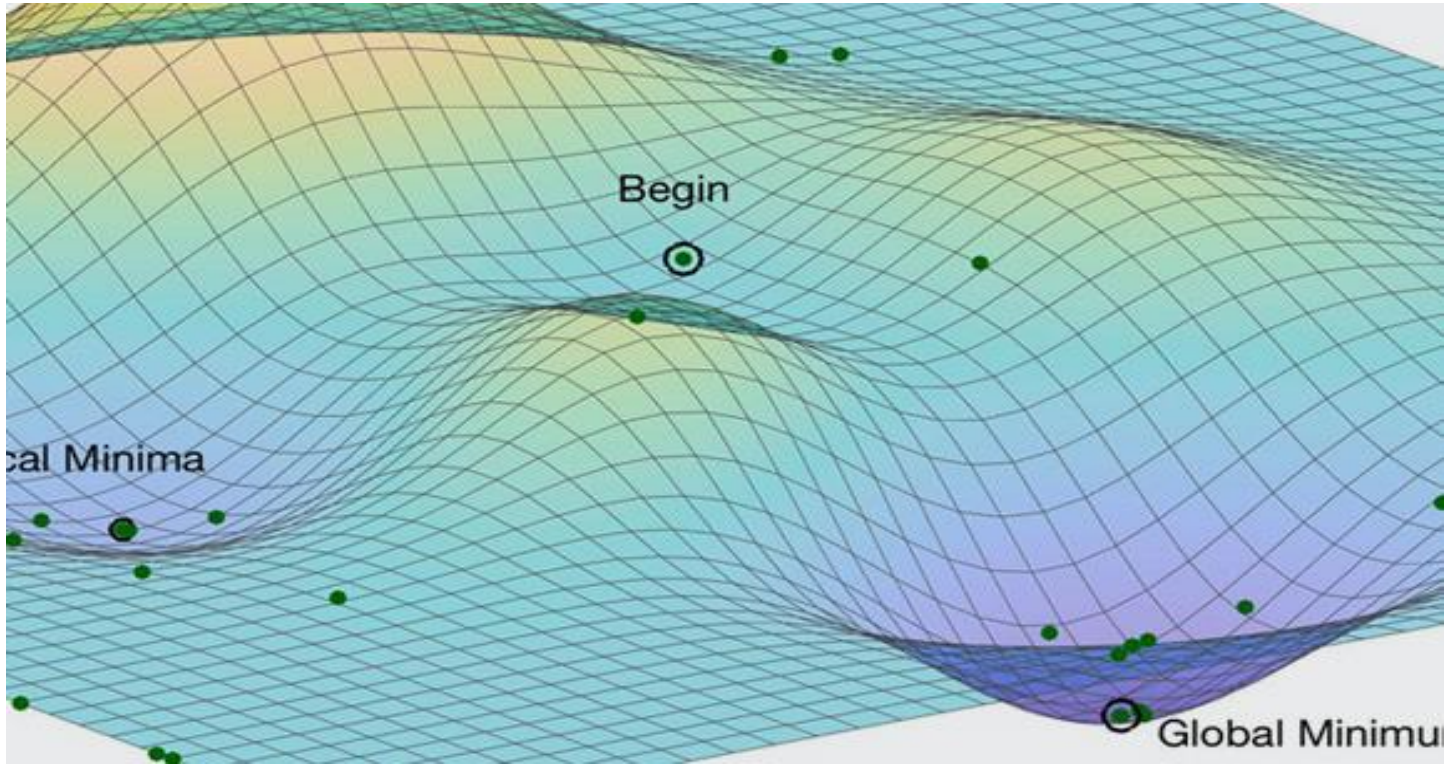
- Operating modes modelled in state flow
- The vehicle operates in Electric , limphome and brake mode
- In brake mode, depending on battery SoC, Regenerative braking is activated

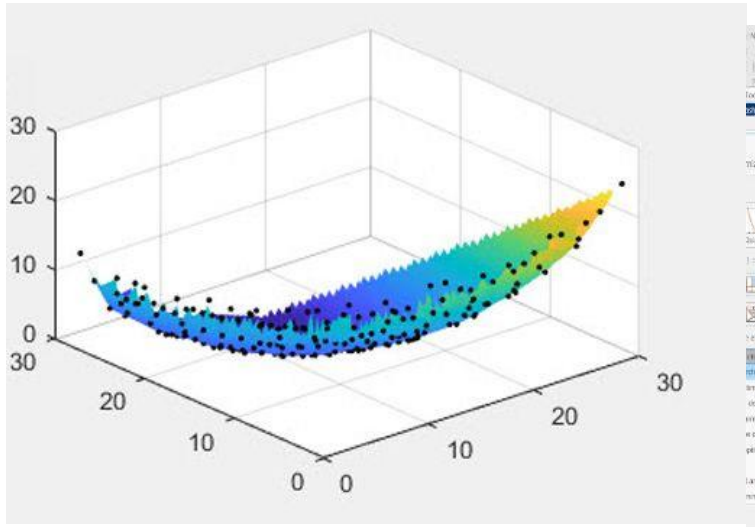
VEHICLE PERFORMANCE – Drive Cycle Analysis

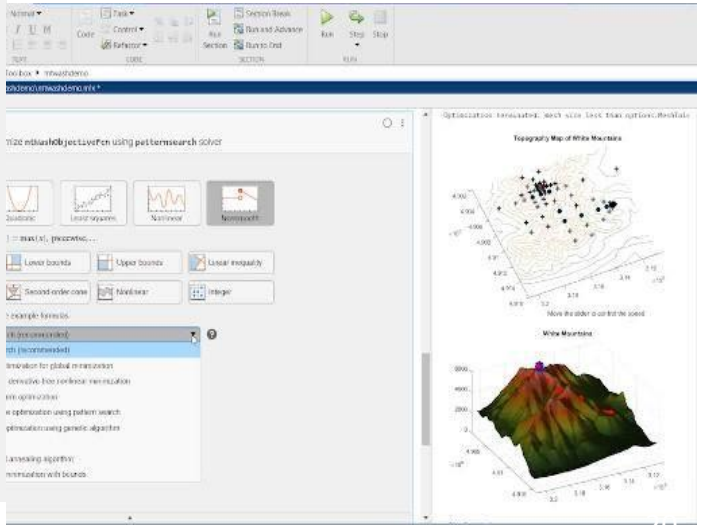


Optimisation

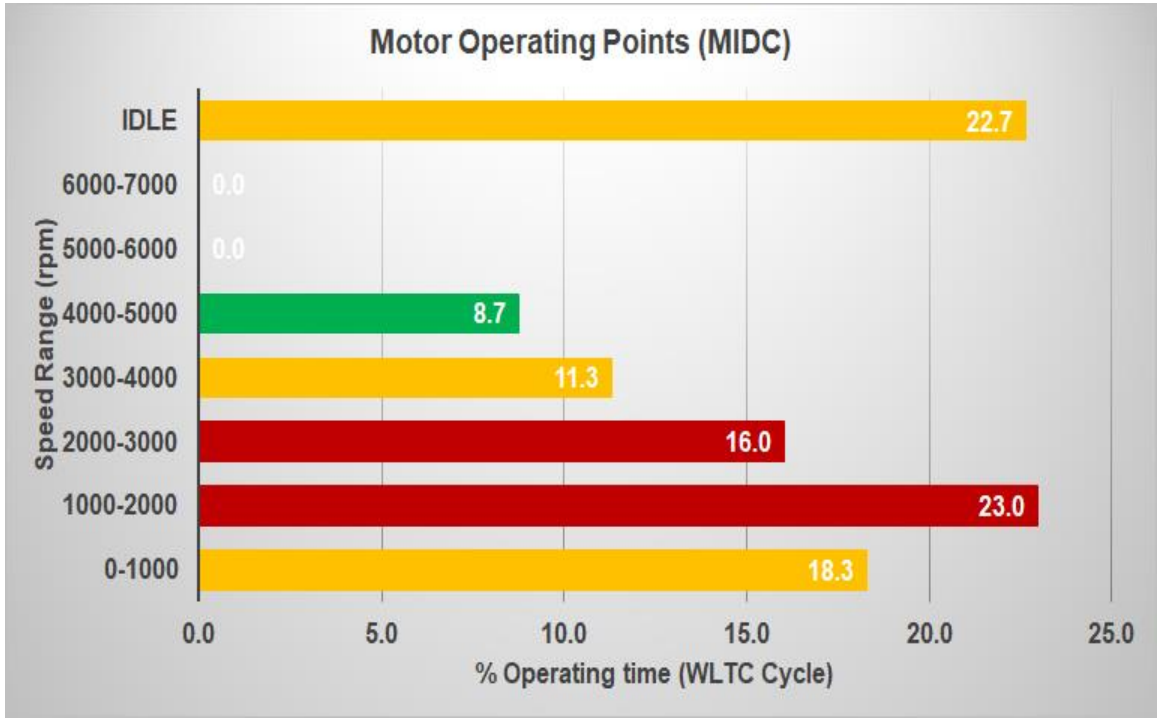
- Range
- Power
- Efficiency
- Gear Ratio
- Operating Speed

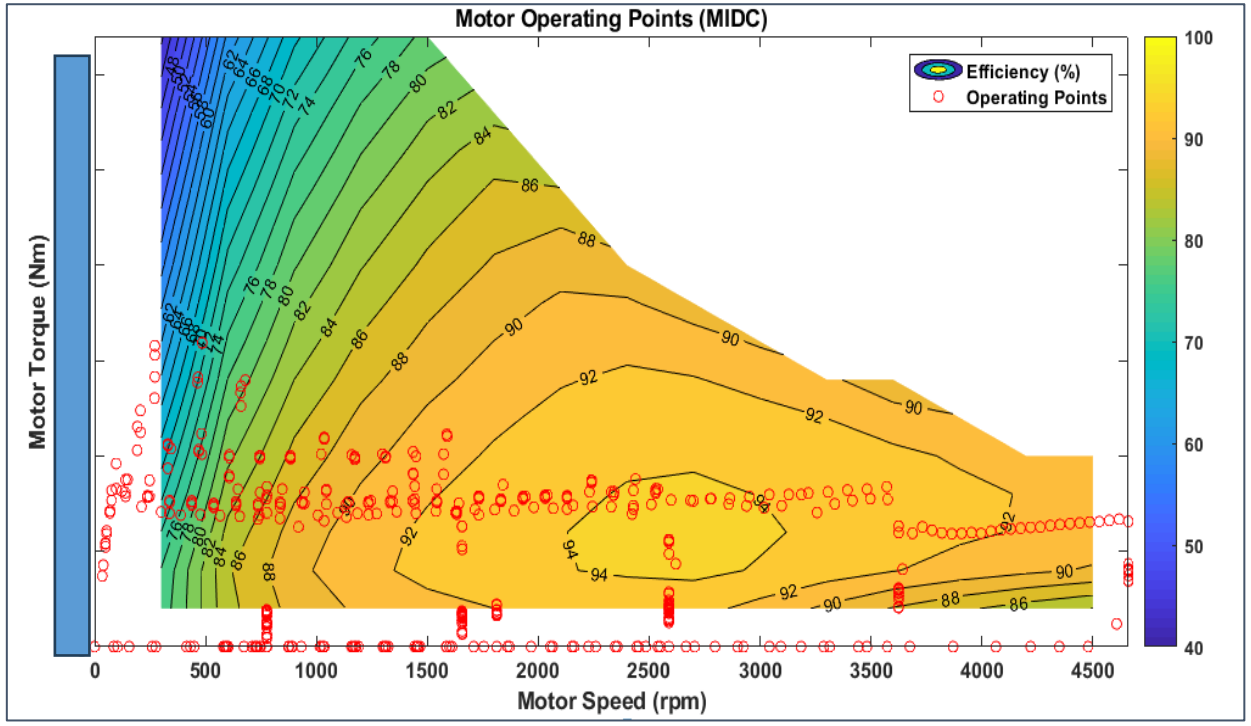






MOTOR OPERATING POINTS





- More than 65% of the time, the motor operates under 4000 rpm for this gear ratio of 1.2
- 750 rpm to 5000 rpm mid load conditions are ideal operating points for motor

Summary

Efficient E-Drive is the need of the hour in the EV segment

Model based design approach helps in realising an efficient E-Drive for a given set of requirements & Constraints

Mathworks tools are powerful aids for the model-based design

Thank you