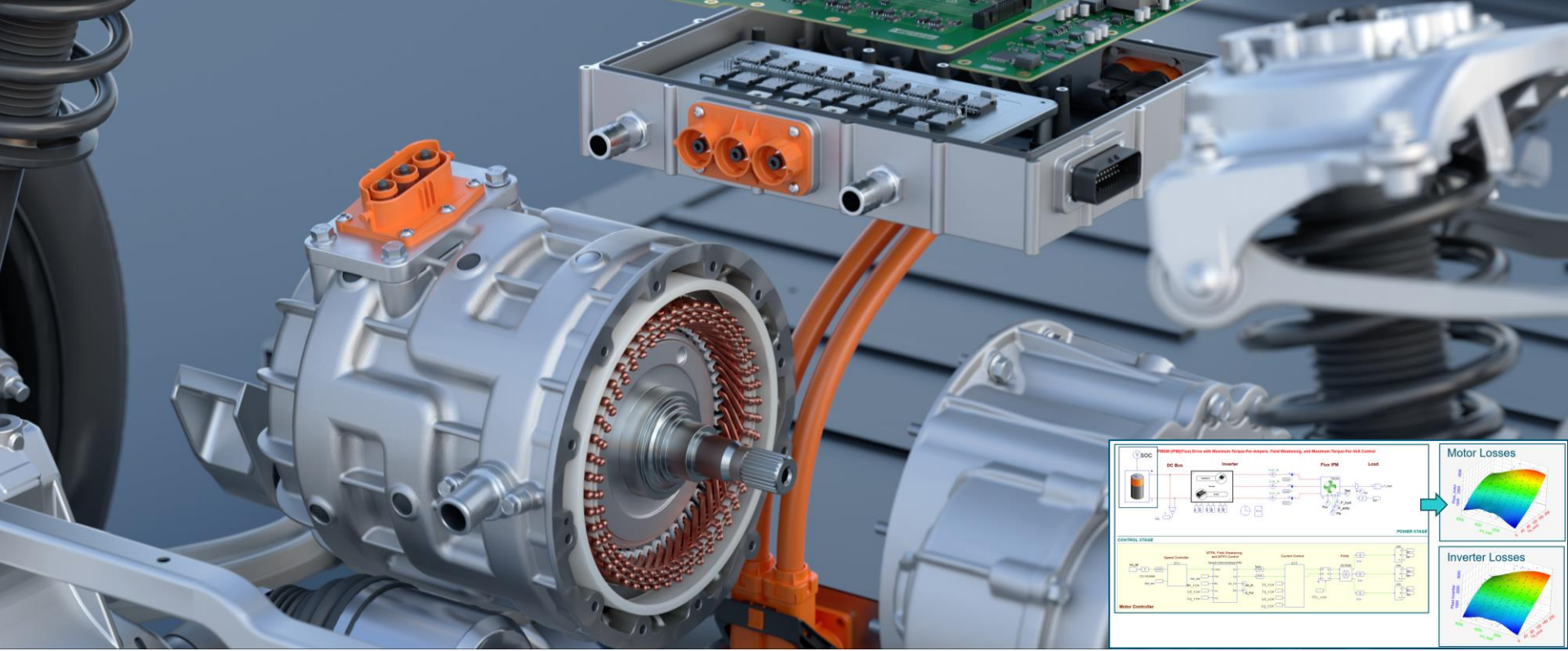

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FAST TRACK EDRIVE EFFICIENCY MAPS WITH PSIM & HYPERSTUDY
NO TEDIOUS SETUP – NO SCRIPTING

Nikos Dimitrakopoulos | Sr. Solution Engineer

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Introduction

Fast Track eDrive Efficiency Maps No Tedious Setup – No Scripting

Nikos Dimitrakopoulos

Sr. Solution Engineer GTT

Power electronics & Integrations

- PSIM
- HyperStudy
- Twin Activate

- ✓ **This will webinar will be recorded→ YouTube**
- ✓ **The slides & simulation files will be shared**

Agenda

- Introduction to efficiency maps
- Creating efficiency maps without scripting - linear motor
- Maximizing fidelity – to – simulation time ratio
- Working with multi-dimensional efficiency maps
- Deploying efficiency maps as fit models in WLTP drive cycles

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Siemens Acquisition – Closed March 2025

The current history of PSIM. The original founder, Dr. Hua Jin and development team is still active

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INTRODUCTION TO EFFICIENCY MAPS

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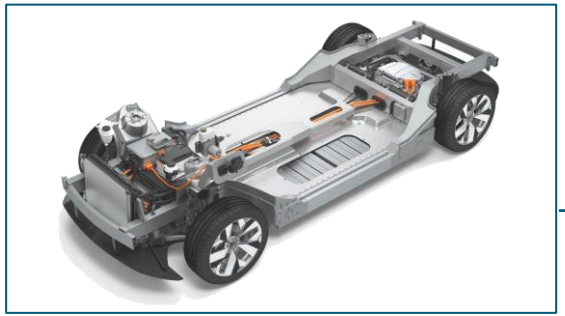
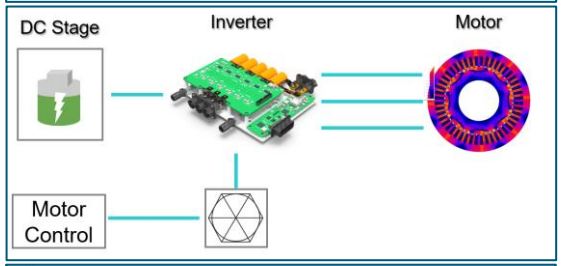
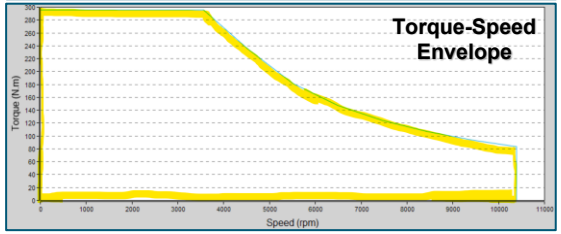
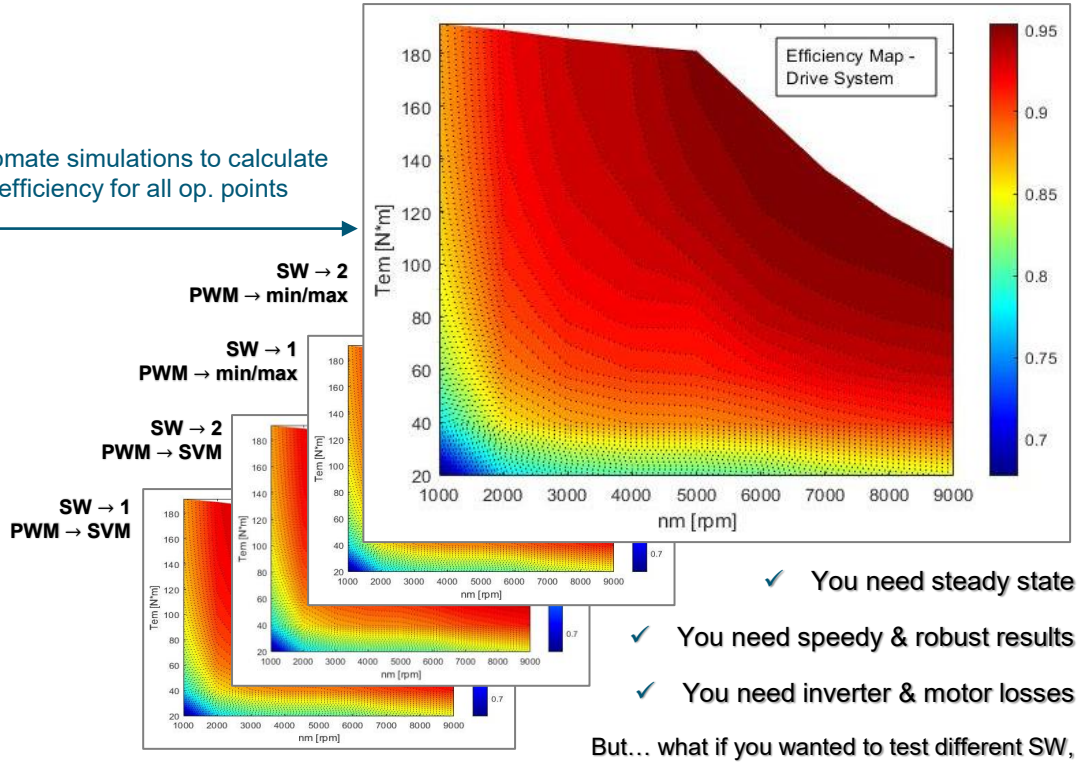
Introduction to efficiency maps







Automate simulations to calculate efficiency for all op. points



- ✓ You need steady state
- ✓ You need speedy & robust results
- ✓ You need inverter & motor losses

But… what if you wanted to test different SW, motor designs, fsw or PWM techniques?

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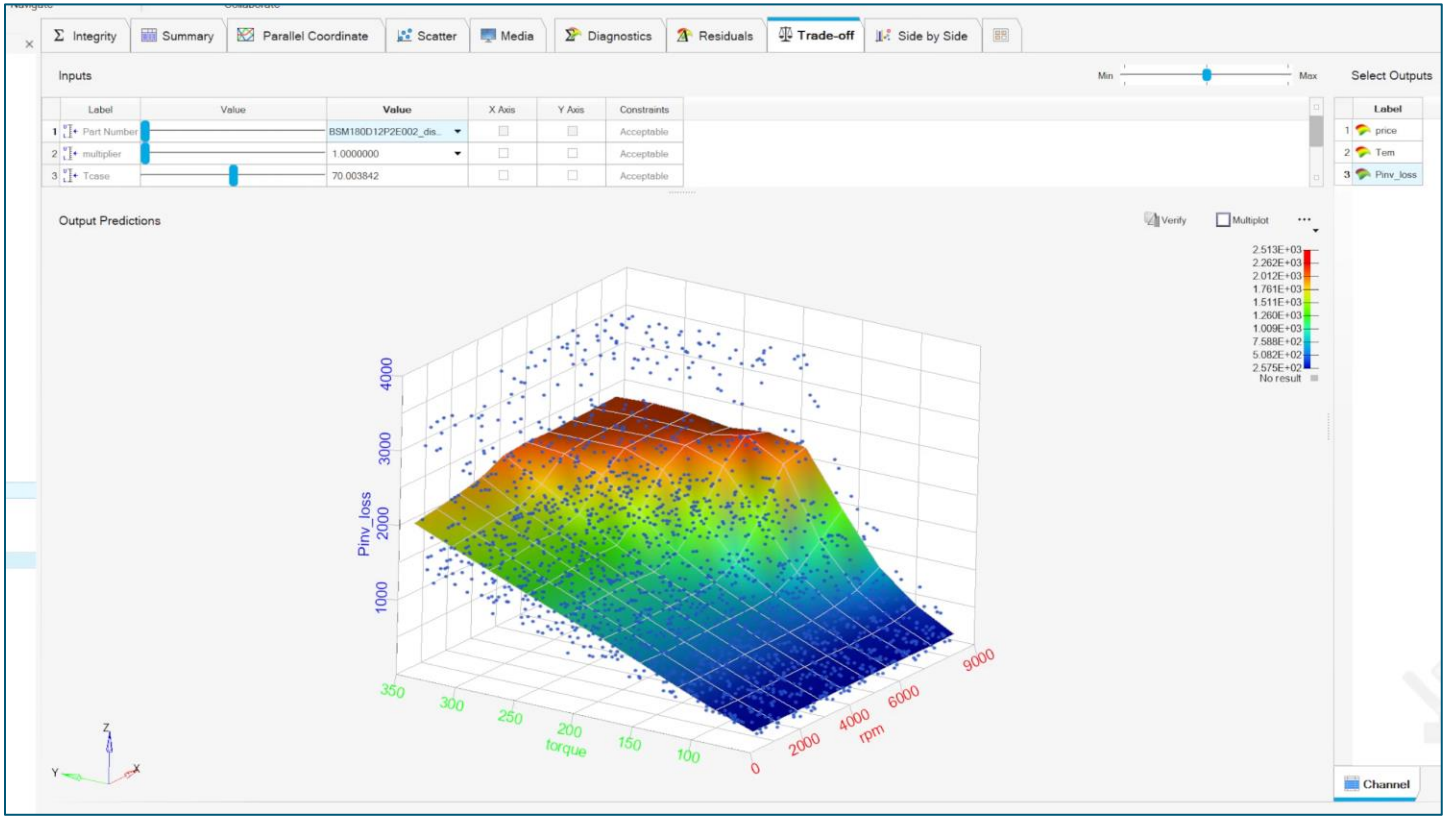
Multi-dimensional efficiency maps



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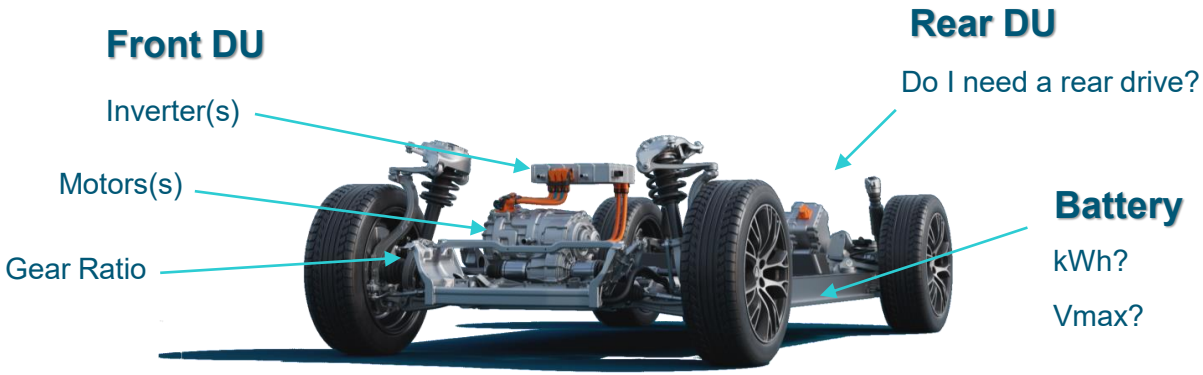
Why are efficiency maps important?

Innovations are driven by system exploration



PSIM

- Explore the limits of the design & market space
- Optimize KPIs while applying requirement checks
- Work with fit models that encapsulate system tradeoffs

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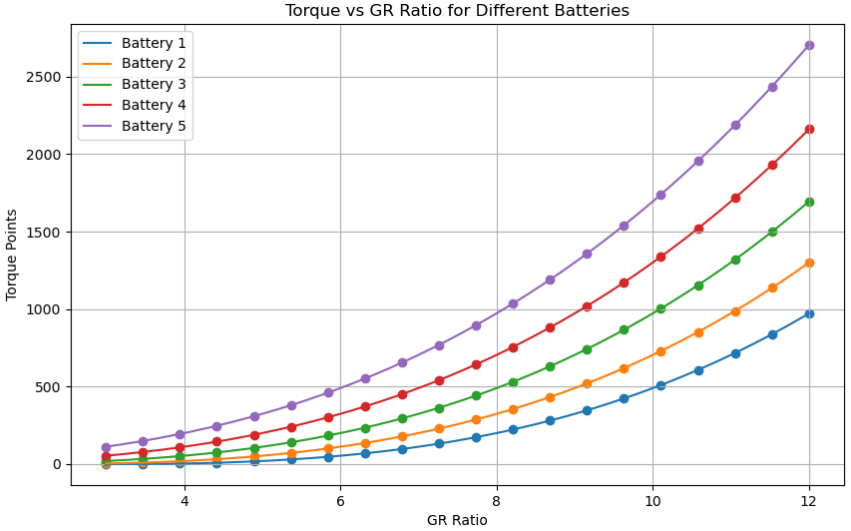
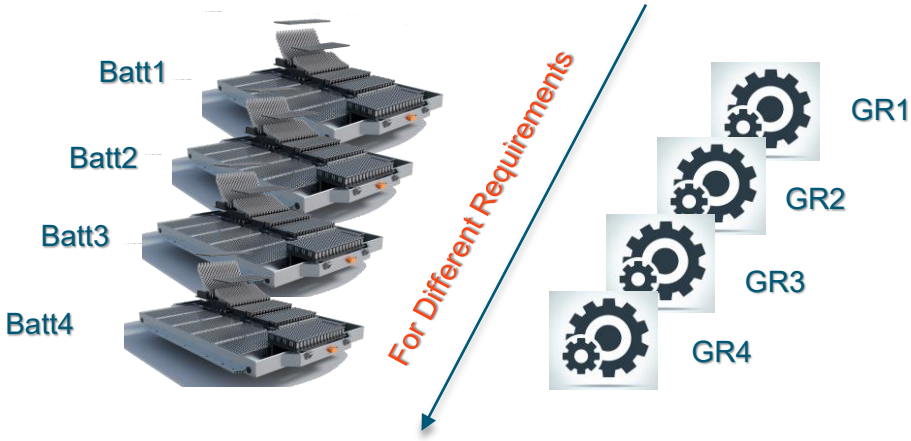
Use case – Size a motor with different GR and Battery Options

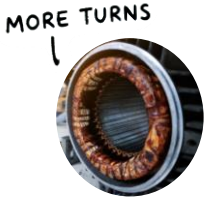
Leverage state of the art simulation tools

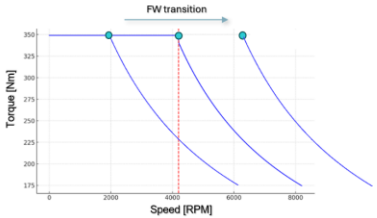




- ✓ What if you could eliminate the rear motor with a specific front GR?
- ✓ What if battery selection prioritizes mass reduction to pass the gradient test?
- ✓ What if adjusting a req. enables more favorable choices for other specs and efficiency?

e-motor Sizing





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Innovations are driven by system exploration

Emphasizing on system losses and costs

⇧⇩ Stands for something positive

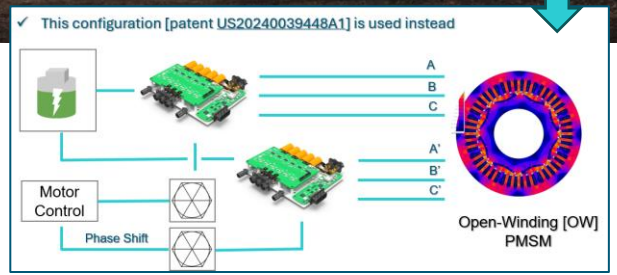
⇧⇩ Stands for something negative

- Voltage ⇧ allows for Np ⇧
- Np ⇧ allows for Ld/Lq ⇧

PWM Losses ⇩

THD ⇩

Greater attenuation of PWM-induced harmonics



Typical Choice per DU

x1 Inverter – PMSM with fewer Np

VS

Innovative Approach

x2 Inverters – for one OW PMSM with more Np

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CREATING EFFICIENCY MAPS WITHOUT SCRIPTING - LINEAR MOTOR

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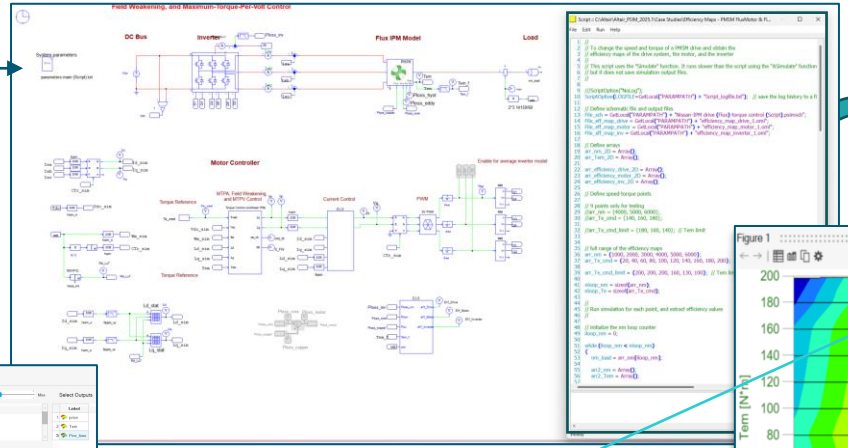
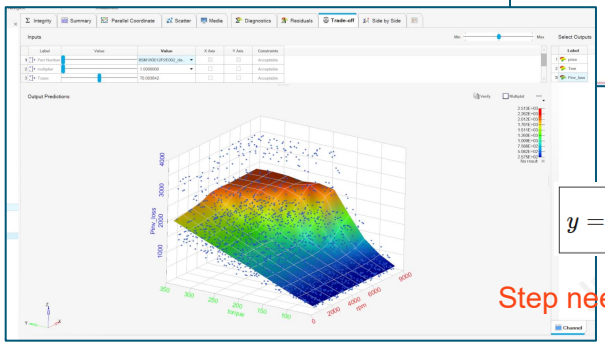
Example – linear motor

Nissan Leaf Like motor – Linear Model

PSIM Automation Options:

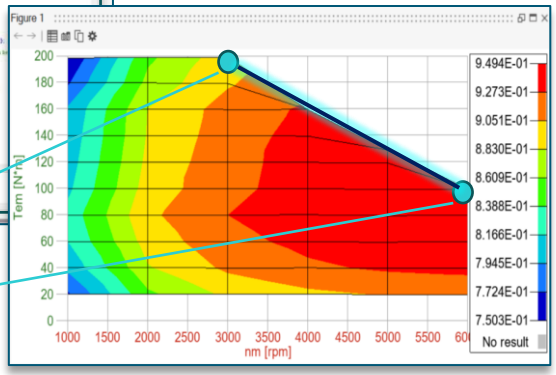
1. Legacy PSIM C scripting
2. Python
3. Altair Compose OML
4. HyperStudy : NO scripting needed





$$y = -\frac{1}{30}x + 300$$

y = ax + b
(3000, 200)
(6000, 100)



Step needed to define envelope in HSt

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PSIM | Creating Efficiency Maps

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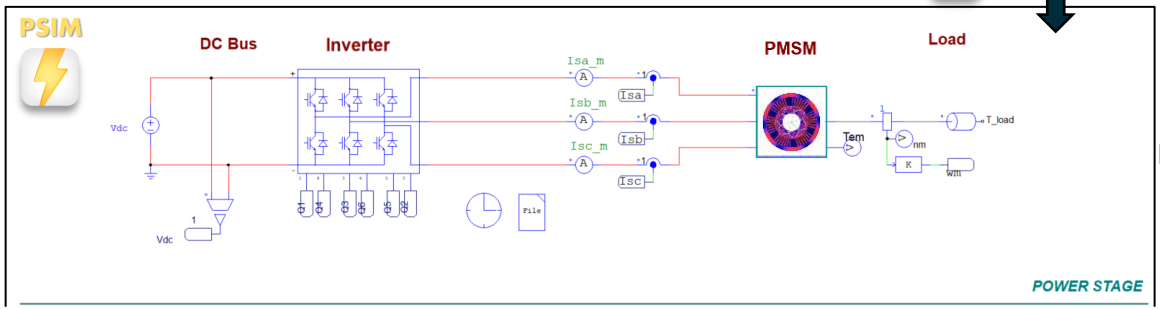
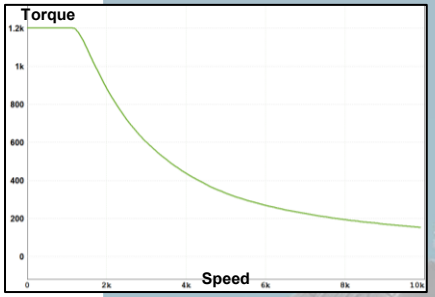
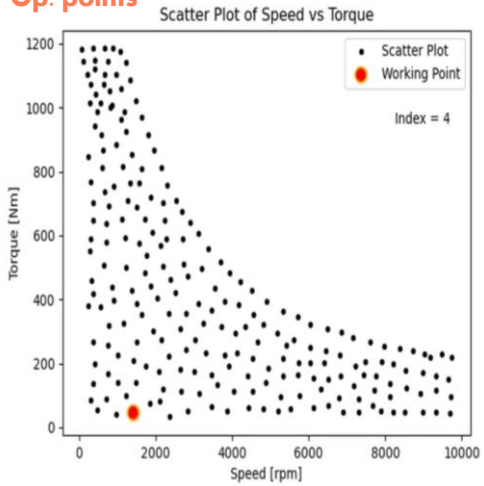
No scripting!

HyperStudy

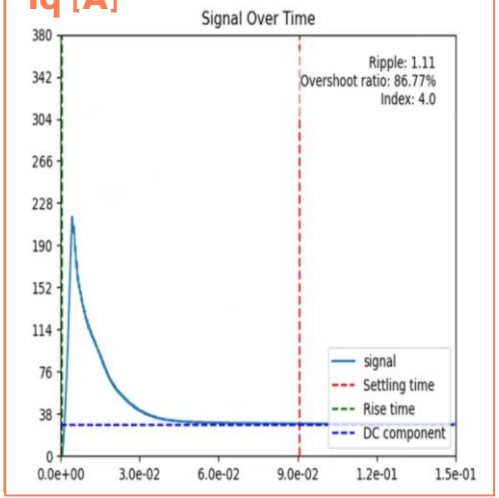




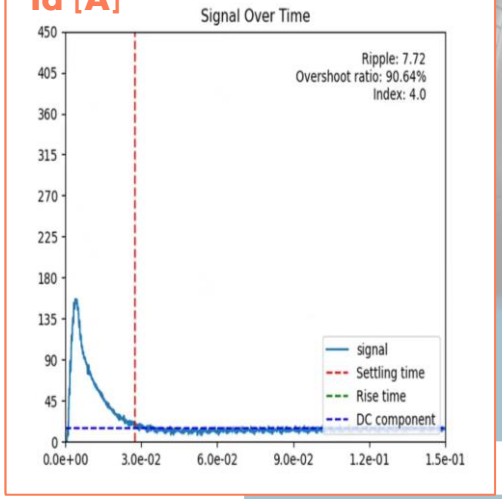
Op. points



Iq [A]



Id [A]



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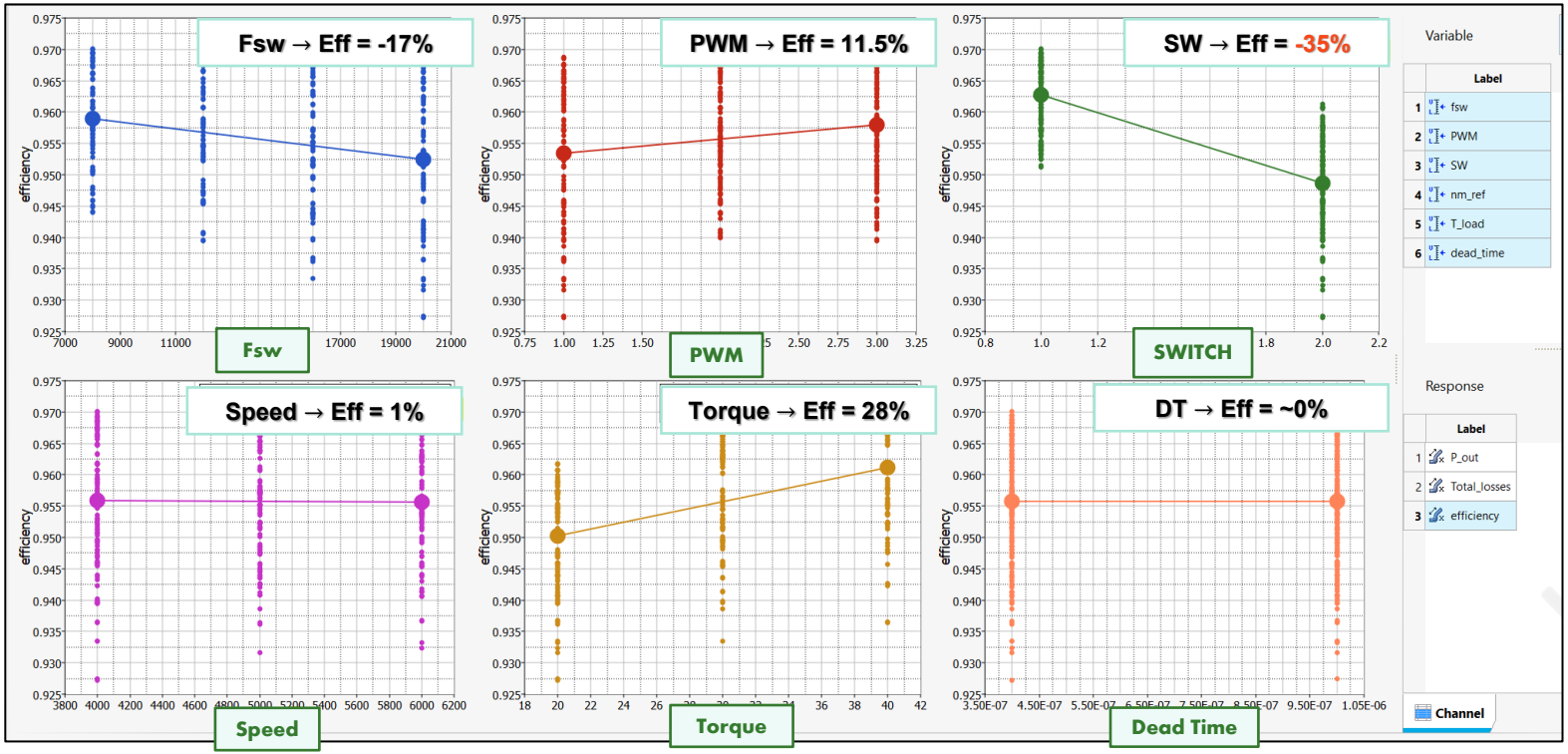
Design Space Exploration on E-Drive Design

Identify system trends



PSIM

HyperStudy

What affects efficiency the most?

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Tips for Efficiency Map creation

1. Use a **torque control system** → speed load avoids inertia effects and reduces total time to steady state
2. Only use the “Torque Control” blocks of PSIM if you don’t have FEA generated Id,Iq references → prefer FEA Id,Iq LuTs
3. The Torque Control blocks are not taking Rs into account
4. T_shaft relates to friction – make sure to set a large value (>=100) to avoid significant friction effects
5. Don’t use the Speed-Torque Curve feature for non-linear motor models (featured removed in **PSIM v2025.1**)
6. Use 50 points per cycle as the time step or more – PSIM optimizes calculations around switching events
7. Minimize sim time by leveraging the steady state block and using adaptive time step based on fsw selection
8. Don’t use dead time! Minimal effects in efficiency anyways

Specifically for the Flux models

1. When you generate the .mat file from FluxMotor, use 1 full electrical cycle option. Not half cycle
2. Adding more op. points for the .mat file (Flux LuT) leads to smoother results. Especially if big changes are observed in between op. points
3. For the motor controller, it is important to watch the phase margin (in the parameter file) and Vma signal to ensure stability
4. Make sure that the PSIM considers the same maximum current limits, DC bus voltage and modulation technique as Flux
5. In case of .mat files with non-zero initial rotor angle, please make sure to use **PSIM v2025.1 or later**

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INCREASING FIDELITY WITHOUT COMPROMISING SIMULATION TIME

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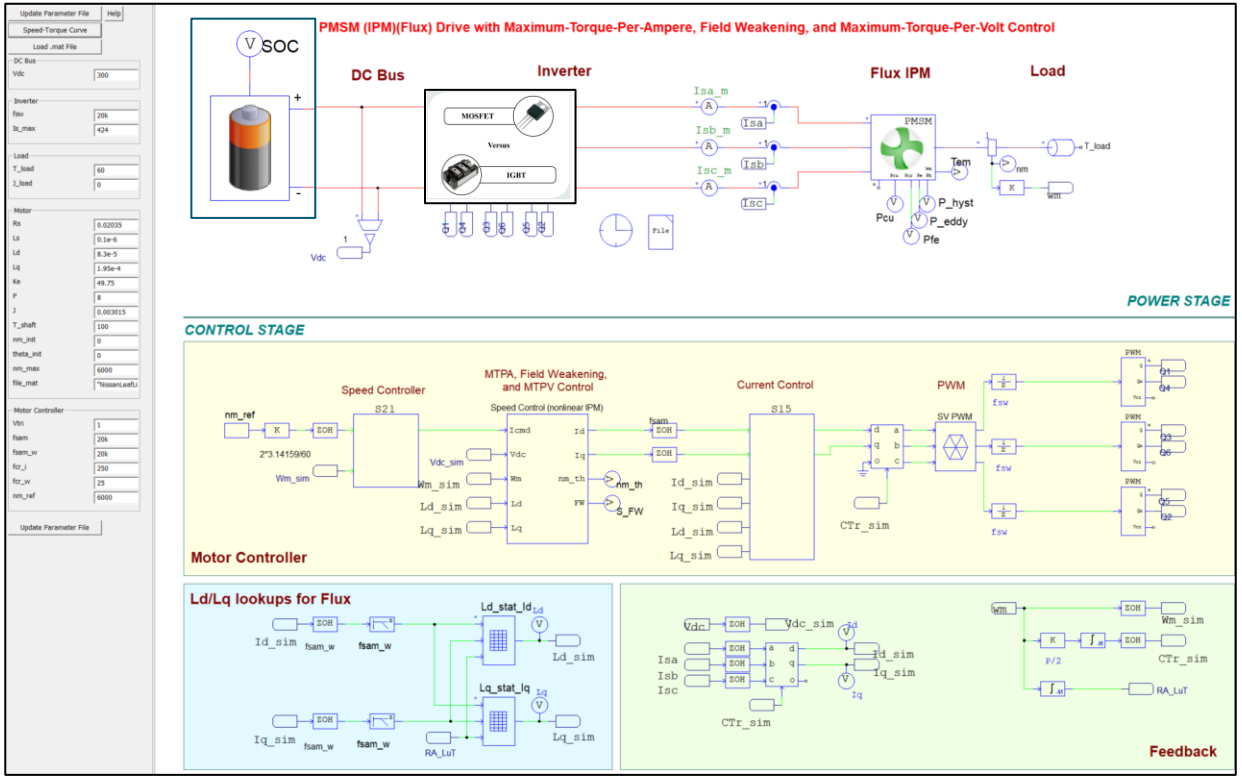
The metric that matters: fidelity to simulation time ratio!

- Motor Losses incl. core loss
- LuT based approach
- Work around your own motor
- Thermal switch models
- Dynamic battery models

Directly from Datasheets



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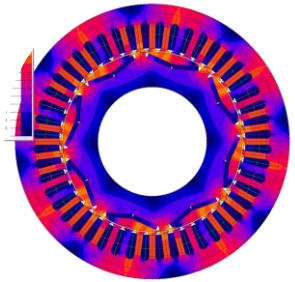
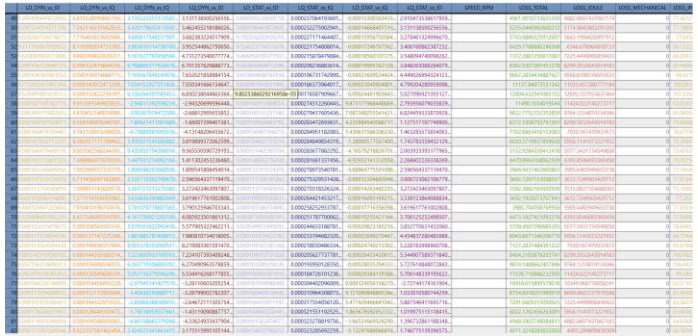
How the Flux – PSIM link wokrs

Work around your own motor geometry

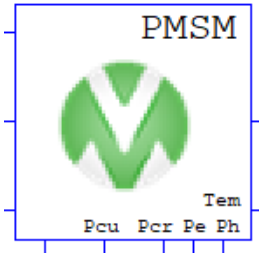
Flux or Flux Motor



.mat export with macro

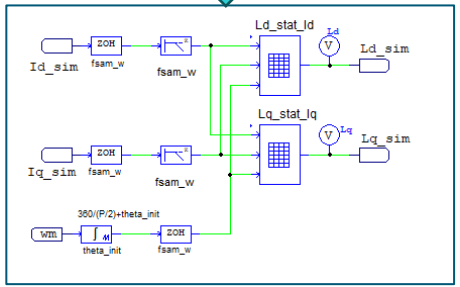


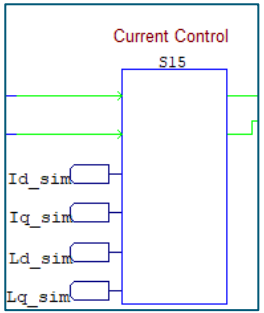
Flux/Flux Motor PSIM model



High-fidelity & non-linear effects captured:

1. Saturation
2. Spatial harmonics
3. Cogging torque
4. Copper losses
5. Eddy current and Hysteresis losses





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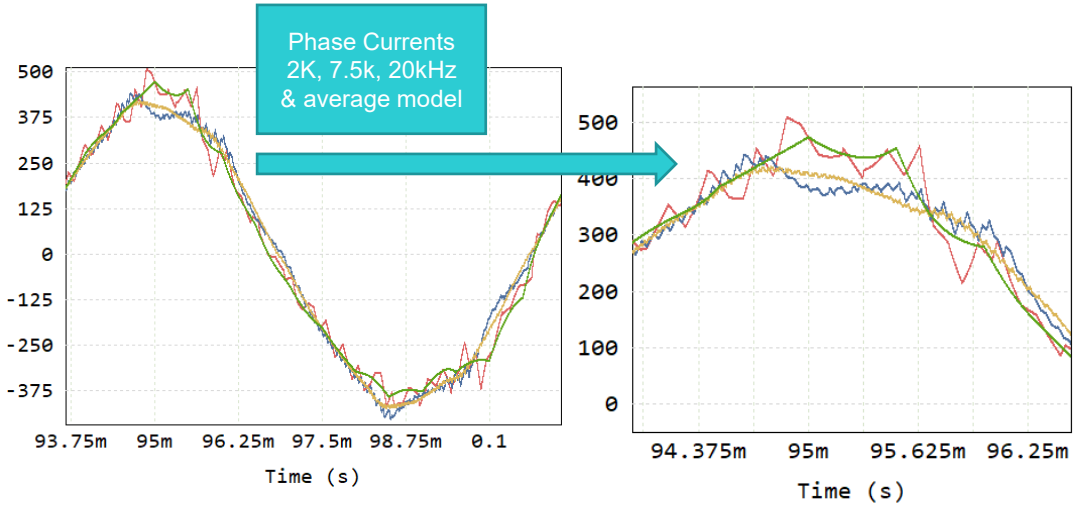
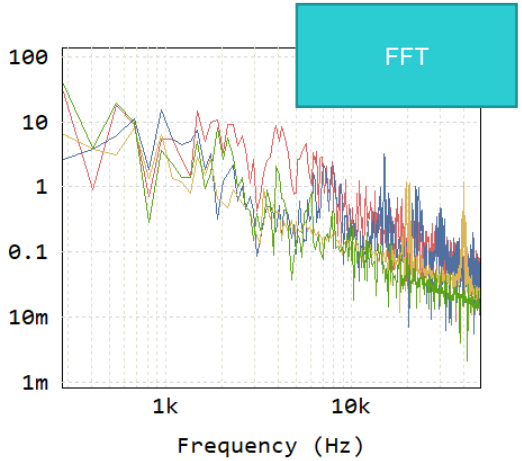
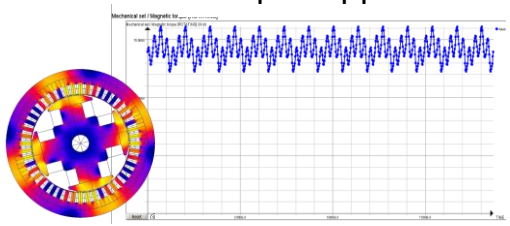
The Fidelity of the Inverter Drives Harmonic Content

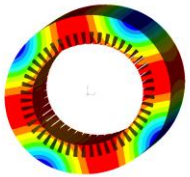




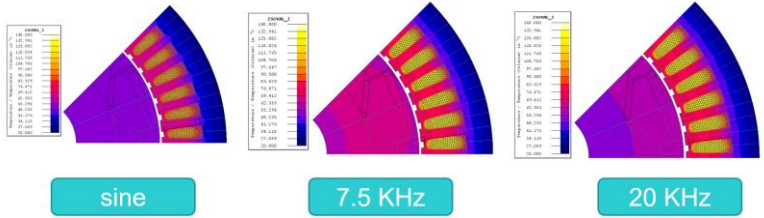
Torque Ripple



Vibration & Noise



Losses from Harmonic Rich currents



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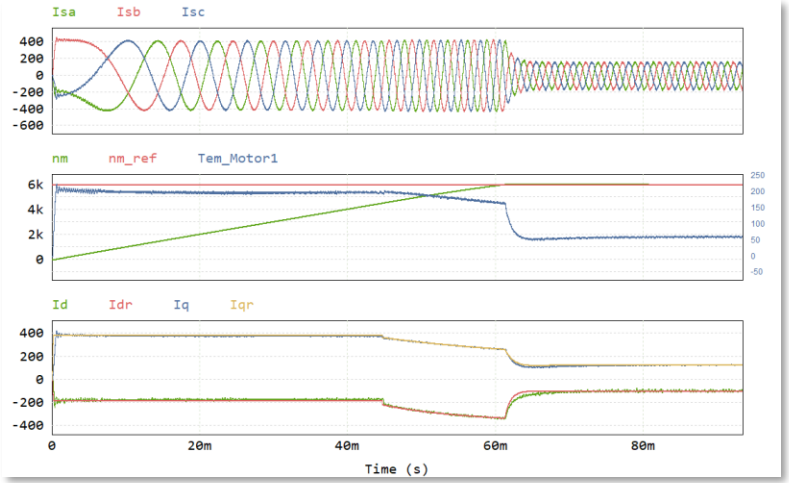
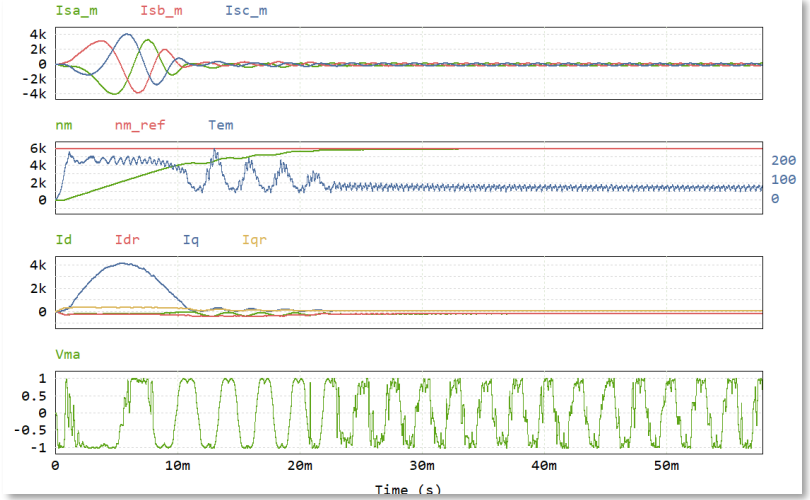
Example – Flux motor model

Nissan Leaf Like motor – Flux Model

- Motor control setup is identical
- Switching 20kHz; Cross frequency current loop 2kHz, speed loop 200Hz





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Common issues with Flux models

1. **The control design may require more effort**. Flux models increase fidelity by adding saturation effects & spatial harmonics
2. **Significant discrepancy between the torque curves generated by PSIM versus FluxMotor**

Ld and Lq are changing with Id,Iq and rotor position → remember that this affects the torque equation!

In the dq0 frame, the developed torque can be expressed as:

$$T_{em} = \frac{3}{2} \cdot \frac{P}{2} \cdot (\lambda_{pm} i_q + (L_d - L_q) i_d i_q)$$

Therefore, PSIM's torque-speed curve is accurate only for a linear PMSM model and removed from v2025.1 onwards

3. **When using the model that ignores rotor position, the control runs much smoother**

Ignoring rotor position keeps saturation effects in play but disregards spatial harmonics making torque ripple less evident.

This can help with the controllability of the machine in cases where the primary goal is system-level simulation or efficiency map creation

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WORKING WITH MULTI-DIMENSIONAL EFFICIENCY MAPS

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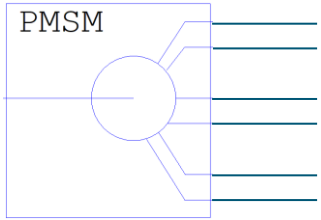
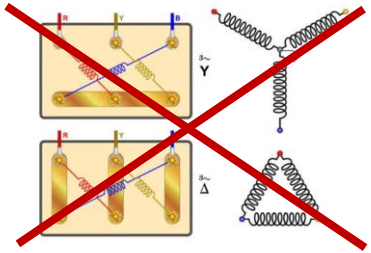
What if we could increase the available voltage?!

What are the benefits to system level efficiency?

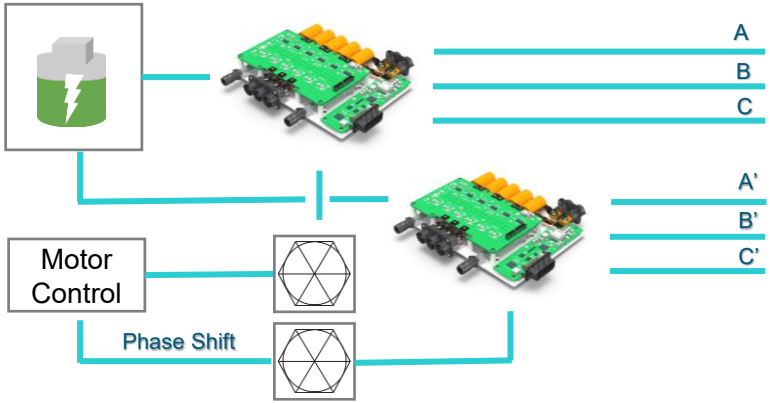


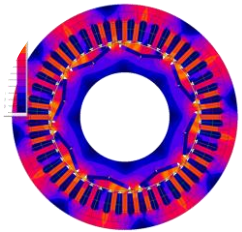
- The EV9 motor has six exposed winding ends
- Is this a Star vs Delta discussion?



- ➢ The available voltage is effectively increased, allowing for more favorable design tradeoffs
- ➢ Imagine switching to a battery pack voltage of over 1 kV for 'highway' mode!

✓ This configuration [patent US20240039448A1] is used





Open-Winding [OW] PMSM

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Let's visualize the design space

Is adding a second inverter is viable?

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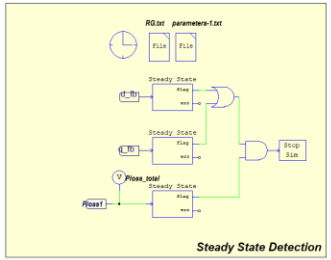
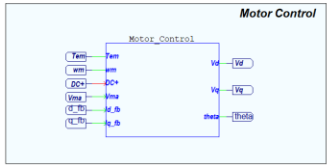
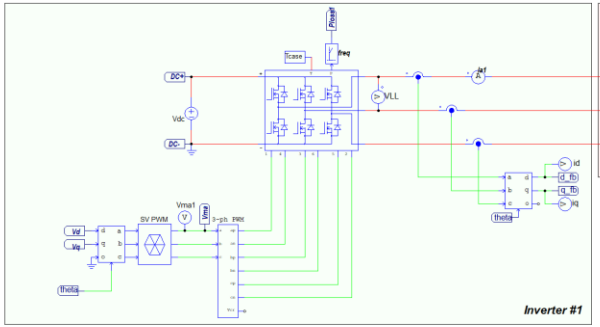
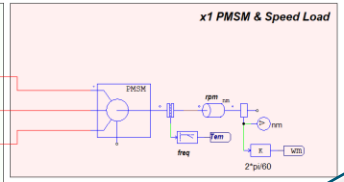




Scenario #1
[Inverter x1]
[Fewer turns]



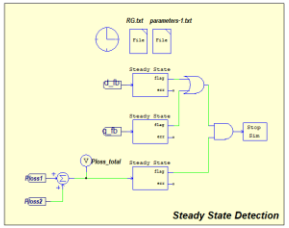


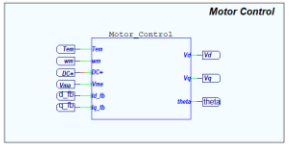
Motor Efficiency ⇩

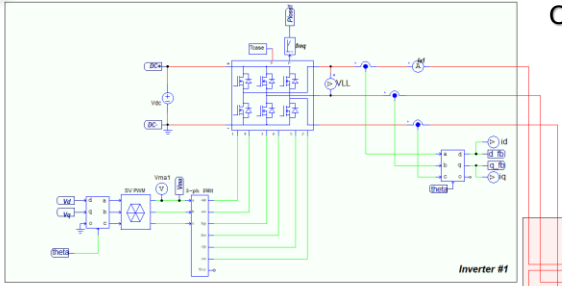
Inverter Efficiency ⇩

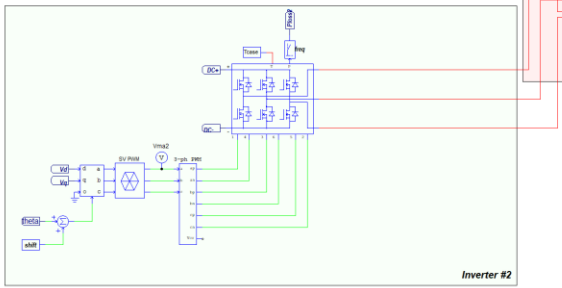
Current Rating ⇧

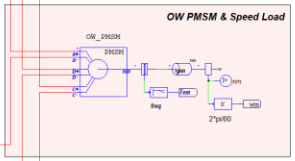
Cost ⇩











Motor Efficiency ⇧

Inverter Efficiency ⇧

Current Rating ⇩

Cost ⇧

*NOT double

Scenario #2
[Inverter x2]
[More turns]

Let’s visualize the design space

Is adding a second inverter is viable?

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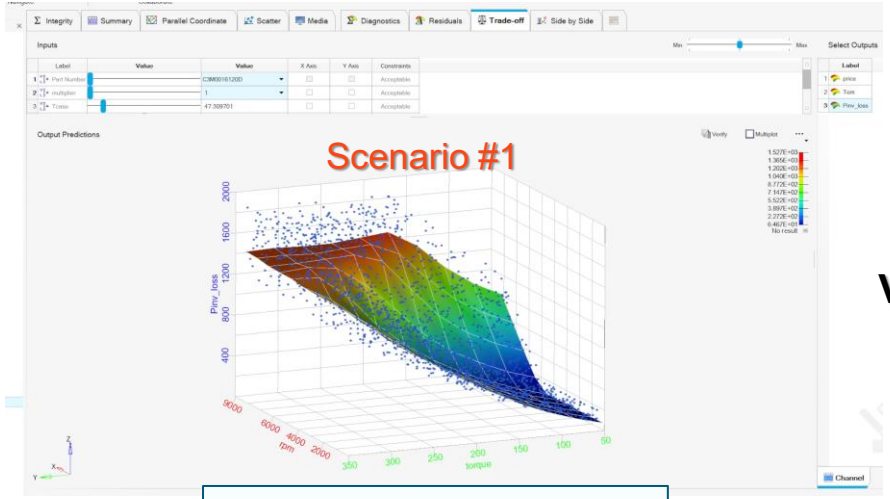


x1 Inverter – PMSM with fewer Np

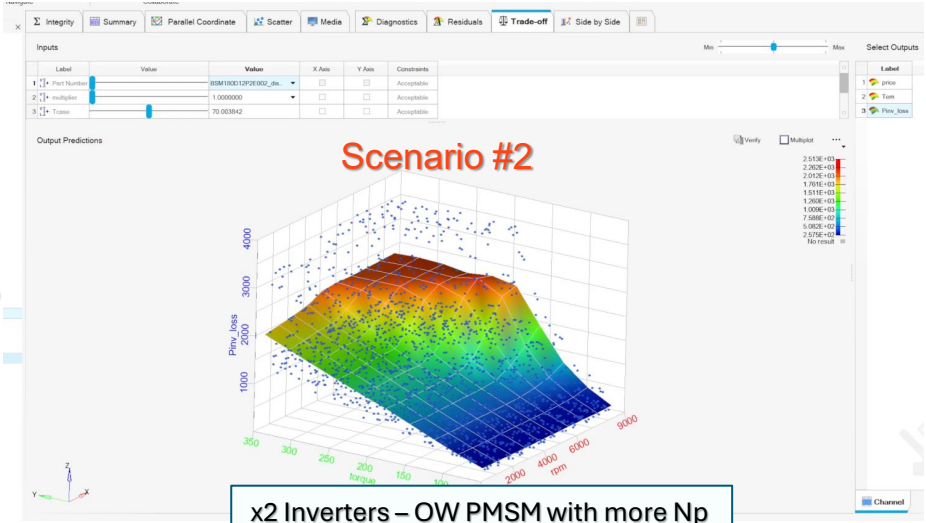
Wolfspeed
C3M0016120D x4 parallel = ~1700 € total

Wolfspeed
WAS300M12BM2 x1 parallel = ~2700 € total

Case Temperature ranging from 40°C to 100°C → cooling

Varying **Rg** to emulate adaptive gate driving

VS



x2 Inverters – OW PMSM with more Np

Wolfspeed
C3M0016120D x3 parallel = ~1270€ x2 = 2540 € total

ROHM
BSM180D12P2E002 x1 parallel = ~1960€ x2 = 3920 € total

Case Temperature ranging from 40°C to 100°C → cooling

Varying **Rg** to emulate adaptive gate driving

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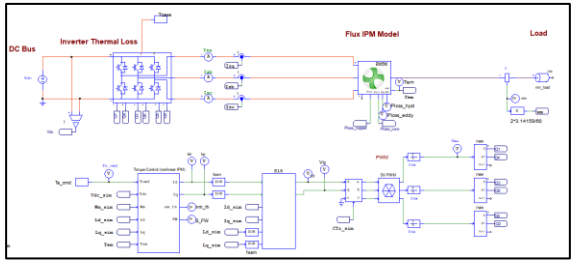
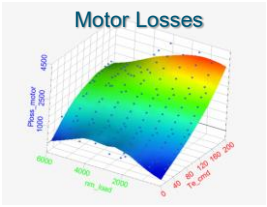
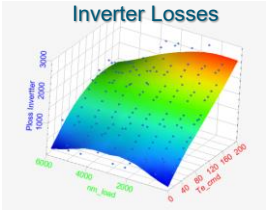
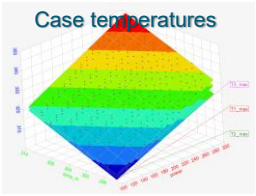
System Simulation with Fit Models

Leverage state of the art simulation techniques

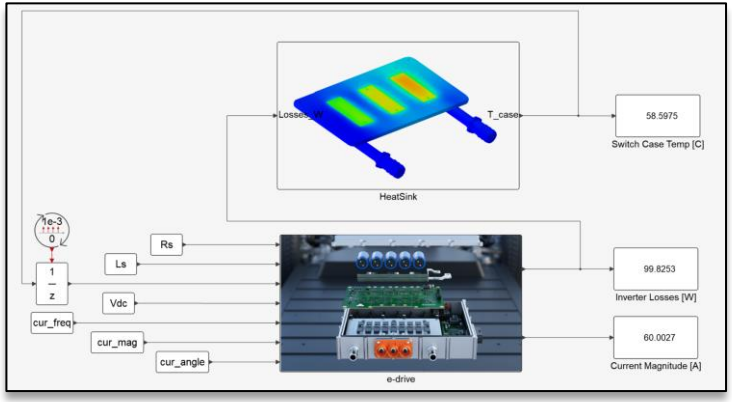








System Level Simulation with Fit Models



- Predictive models in action!
- Regression and fitting based on PSIM training data
- Connect multi time-constant systems
- Are those just buzzwords? – give it a try!

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DEPLOYING EFFICIENCY MAPS AS FIT MODELS IN WLTP DRIVE CYCLES

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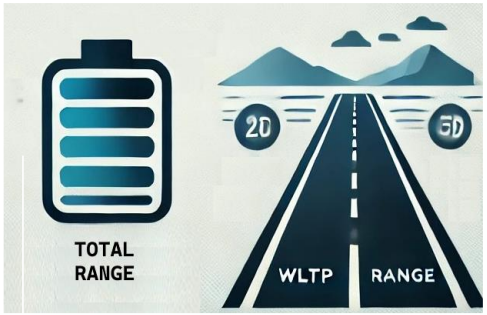
Cross-requirement checks while optimizing

Re-evaluate your requirements if needed



WLTP RANGE

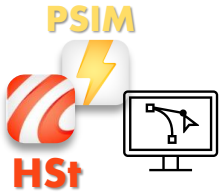
Fit Models change the game in Range analysis

GRADIENT START TEST

Starting torque can penalize Gear Ratio selection

WOT ACCELERATION - Vmax

Explore tradeoffs to achieve Vmax vs grad. start test



✓ You can define system level eff. optimization goals while cross checking requirements!

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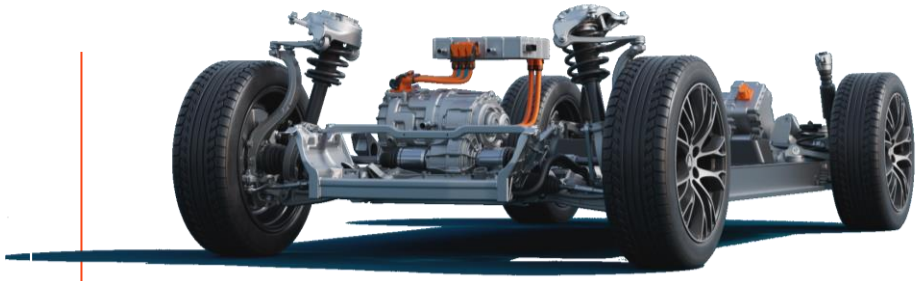
Changing the game in system-level decision making

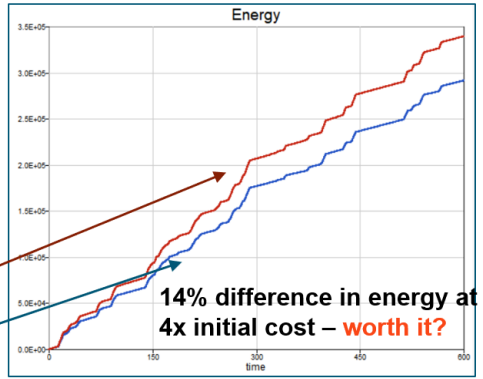
A workflow built to help you visualize and optimize the deign space



Wolfspeed

- C3M0016120D 85A discrete; **4 in parallel**
- WAS300M12BM2 300A rated **halfbridge** module

- C3M – 4x6x $44.5 = $1068
- WAS – 3x $1400 = $4200



EV or Hybrid Powertrain Trade-offs

Assessing a New Vehicle requires Balancing Decisions and Requirements

- Efficiency matters, but requirements can hinder range optimization
- When some requirements just get in the way…

Cross-requirements trade-offs are needed!!

Maximize Every Last Drop of Efficiency - Or Justify the Costs of Not Doing So

EV Range Is a Key Competitive Advantage - Balance Selection and Cost to Stay Ahead

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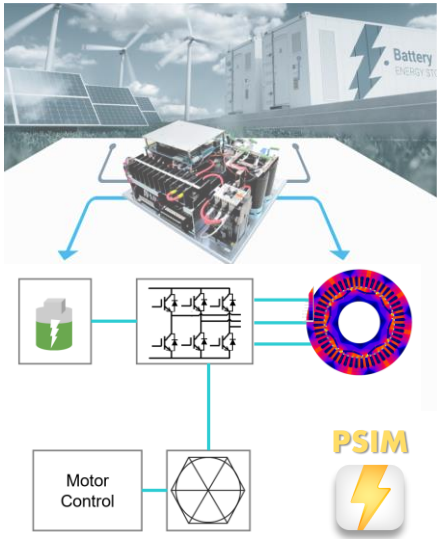
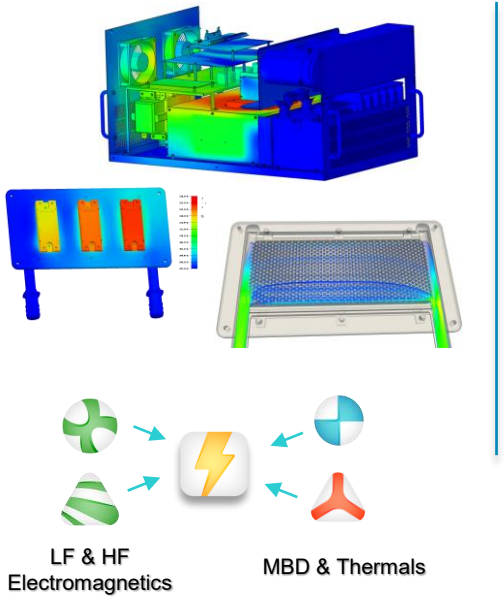
What makes Altair special

The binding factors of modern PE design approach

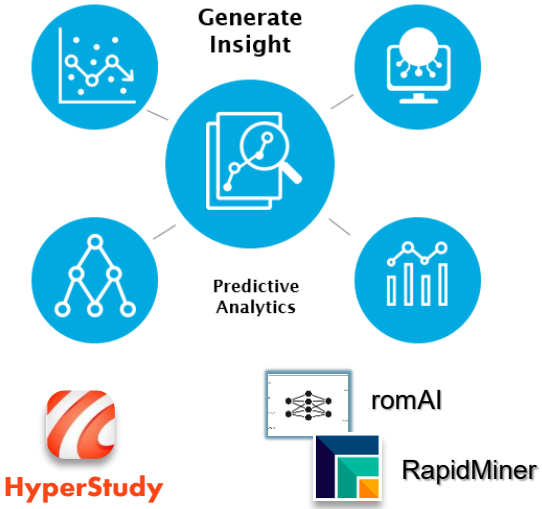
Power electronics solution



Multiphysics couplings



Data – Optimization – AI



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THANK YOU

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