# Optimal Design for Electric Drive Systems

1st October 2019

National Motorcycle Museum

# Company Overview

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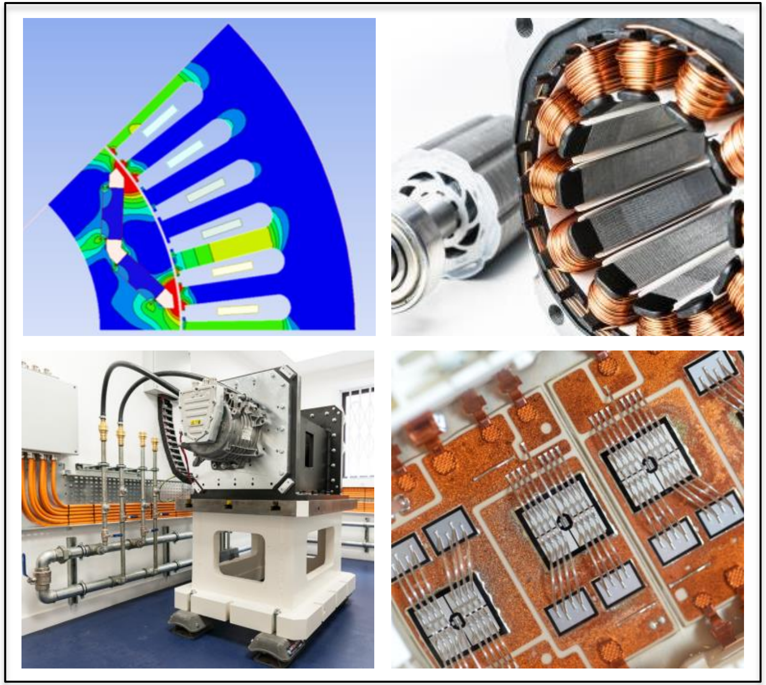
- **Engineering service provider based in the UK**
  - Specialists in electric machine, power electronics, and software development (A/B sample) using state-of-the-art tools
  - Fast turnaround (<12 weeks) of functional prototypes
  - In-house electric machine/power electronics test capabilities
- **Responsive, worldwide support to OEM/Tier1's**
  - Track record of delivering projects in the UK, China, EU, and US
- **100% Intellectual Property handover**
  - Customer owns all IP generated on their project
- **Value Proposition**
  - We provide lean, responsive support for eDrive product development to OEM standards



# System Sizing Tools

# System Sizing Tools

- **The team at eDrive Engineering Services have developed a proprietary tool that uses high-fidelity modelling techniques to objectively optimise electric drive systems.**

- **The tool has the capability of optimising integrated units comprising of power electronics, electric machines, and transmissions to determine the best system depending on customer requirements.**

- **It can also be used to optimise single components in isolation such as the electric machine to determine the best materials and geometries.**
  - eDrive have the capability of assessing the impact of micro-geometry variations on outputs such as torque and power to mass, drive cycle efficiency and noise.

- **It has already been implemented in a number of customer projects with applications ranging from electric pumps to e-Axles for electric vehicle traction.**

- **Each application has prioritized a different major requirement. These range from:**
  - Lowest cost.
  - Lowest mass.
  - Highest drive cycle efficiency.
  - Lowest NVH.
  - Lowest volume etc…

# System Sizing Tools

- **High-fidelity modelling is performed at every level of the chain.**
  - Efficient parametric models driven with Python and VBA scripts have been built to allow eDrive to quickly assess design changes.
  - Each design point is optimised using state-of-the-art methods.
    - Genetic algorithms scan huge design spaces to ensure truly global optimum solutions are found.
    - Proprietary method guarantees that only feasible designs are produced.
    - Manufacturing constraints are built into the tool.
  - Specific data points have been validated using eDrive's in-house test rig.

- **Detailed cost models that incorporate manufacturing processes are also used to facilitate decision-making.**

- **The tool is automated and iterative loops between components can be performed automatically to deliver feasible solutions.**

- **The benefits of this approach are wide-ranging:**
  - Each data point is a feasible, real-world solution.
  - Small variations can be accurately analysed.
  - Accurate predictions of system performance can be made.
  - Sophisticated parameters such as drive-cycle efficiency and noise can also be predicted.

# eDrive's Workflow Tools

- **eDrive proprietary code in Python & VBA script.**
  - Flexible, structured programming languages used to drive Workflow.

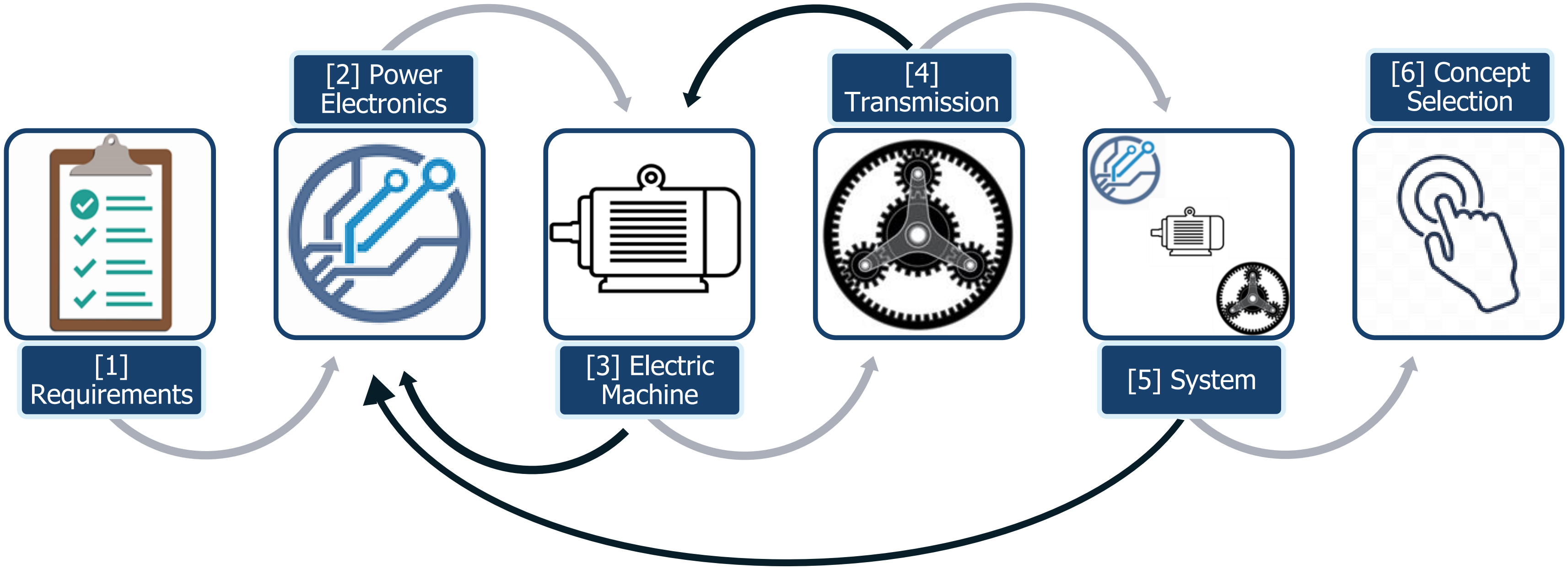
- **ANSYS Workbench & Maxwell.**
  - Customisation and script-driven parametric models.
  - Models are built efficiently to ensure speed without sacrificing accuracy.

- **MotorCAD thermal modelling capabilities.**
  - Thermal circuit analysis shortening turnaround times.

- **HPC via Amazon Web Services.**
  - Parallelisation – solve multiple parameter sets simultaneously (Speed-up proportional to no. of parallel jobs).
  - Multi-core analysis for direct optimization.

# System Sizing Tools

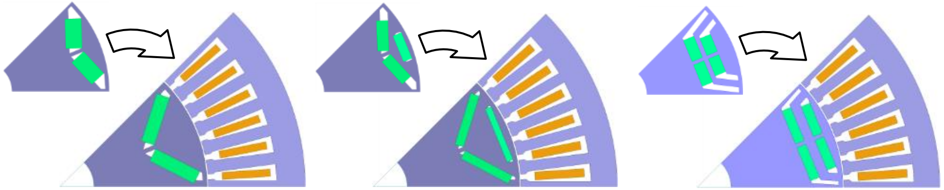
- **A unique capability of the tool is that it can determine the best combination of components for an integrated system.**



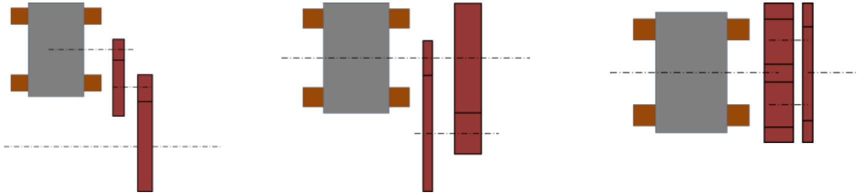
# System Sizing Tools

- **Power electronics:**
  - IGBTs, Silicon MOSFETs, Silicon-Carbide MOSFETS.
  - Numerous voltages, currents, cooling configurations.

- **Electric machine:**
  - Interior Permanent Magnet (IPM – shown in examples), Surface Mount, Polymer Bonded Magnets, Induction machines.
  - Numerous winding types, dimensions, materials.



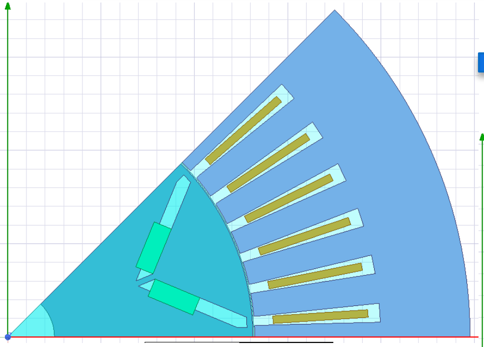
- **Transmission:**
  - Coaxial parallel shaft, Offset parallel shaft, Single and Compound planetary arrangements.
  - Numerous gear ratios, dimensions, materials.



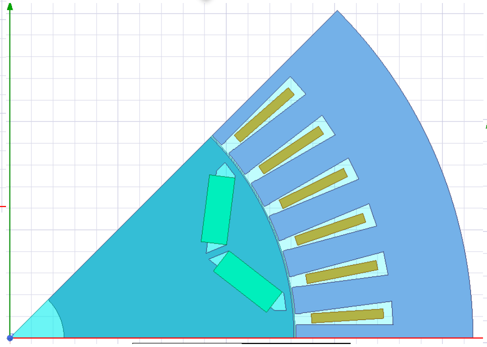
# System Sizing Tools

- The system sizing tool is currently being used as part of a government funded project (IDP14).
- The project scope involves the design, manufacture, and test of an integrated e-Axle (a single unit comprising the power electronics, electric machine, and transmission in one neat package).
- Using various starting points for the components a vast number of real-world designs have been generated.

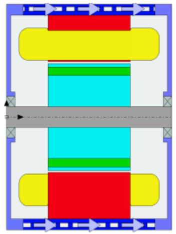
# System Sizing Tools

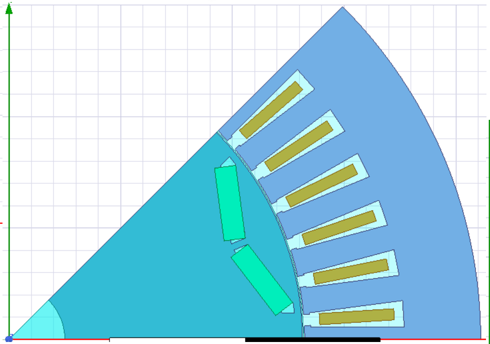


Initial

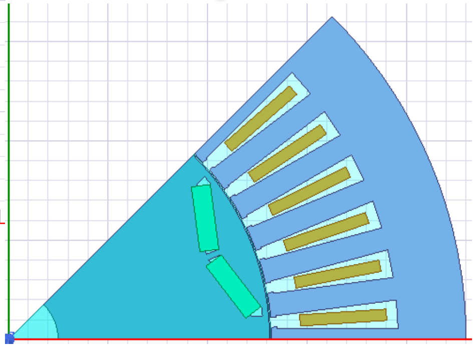


Global Opt



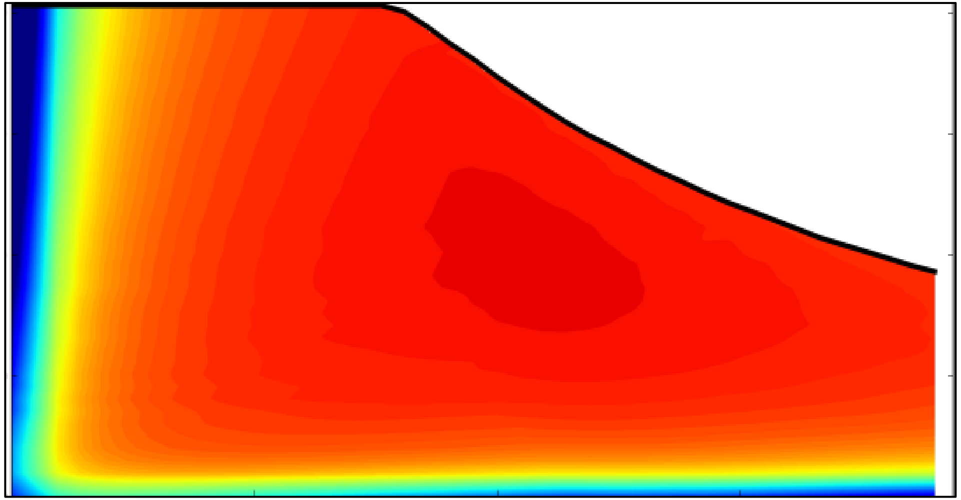


Local Opt

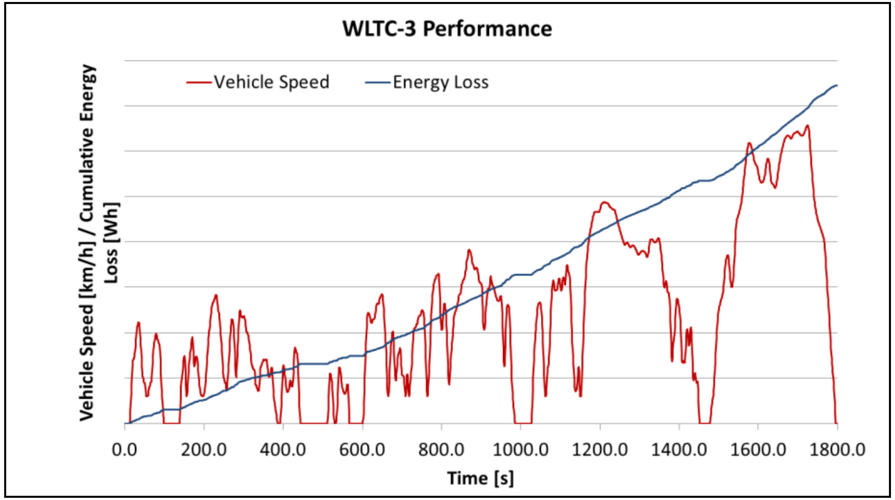


Thermal Opt

# System Sizing Tools



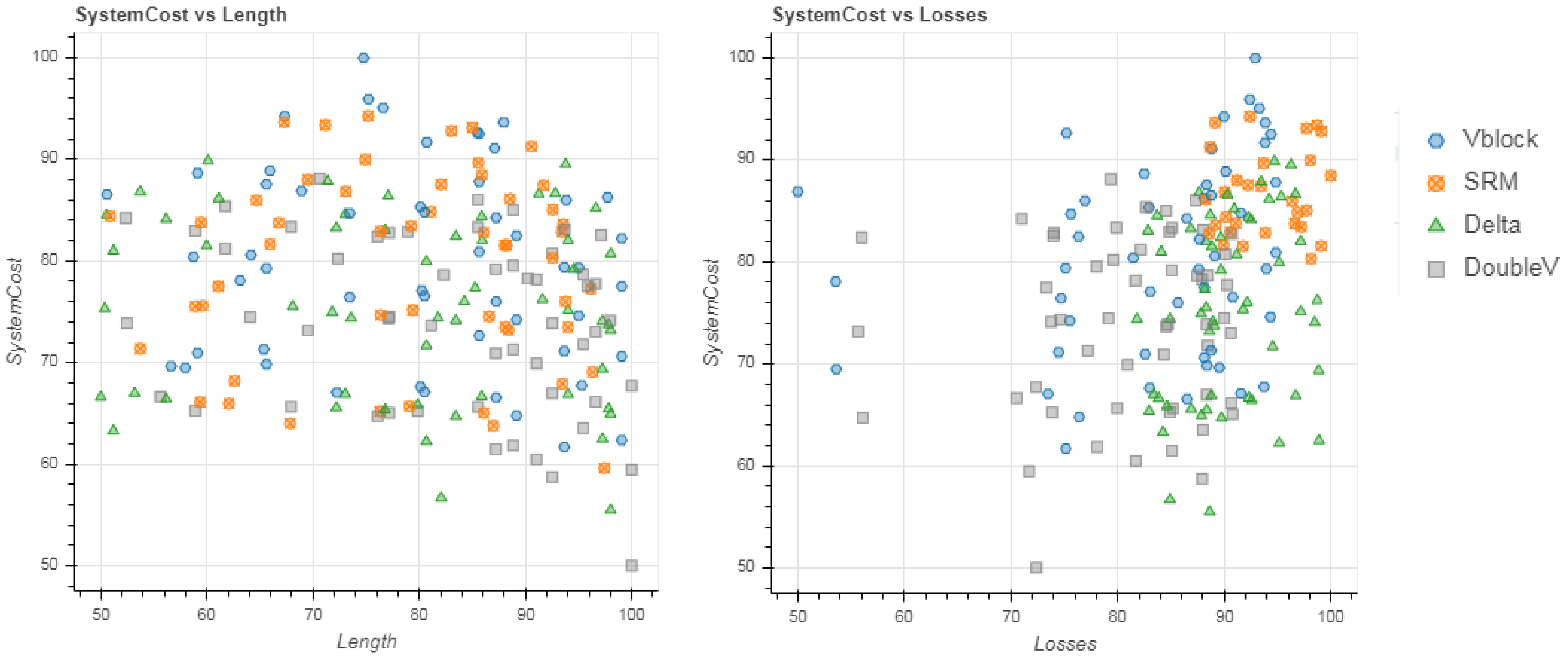
System efficiency map




Cumulative loss over drive cycle

# System Sizing Tools

- Normalized set of results from IDP14 highlighting areas of interest e.g. drive cycle efficiency, volume, torque ripple for 4 different rotor topologies.



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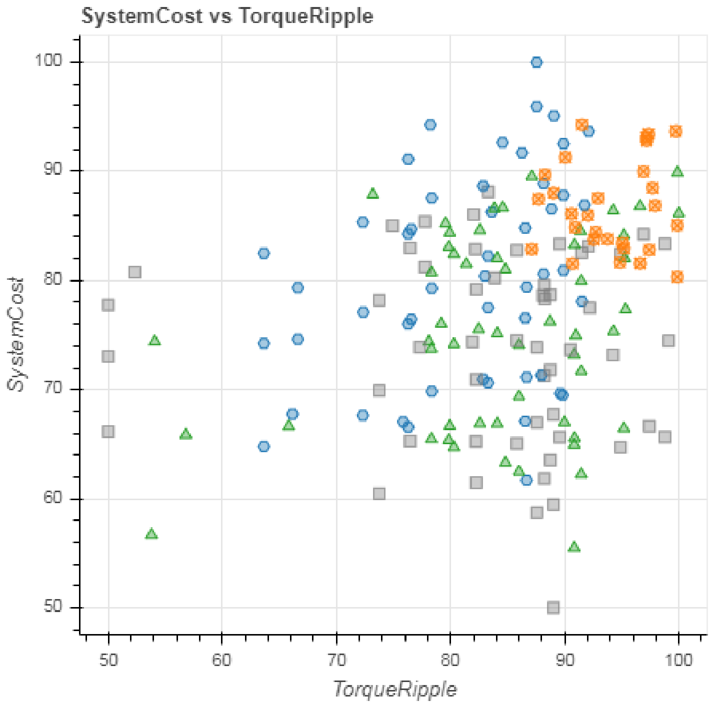


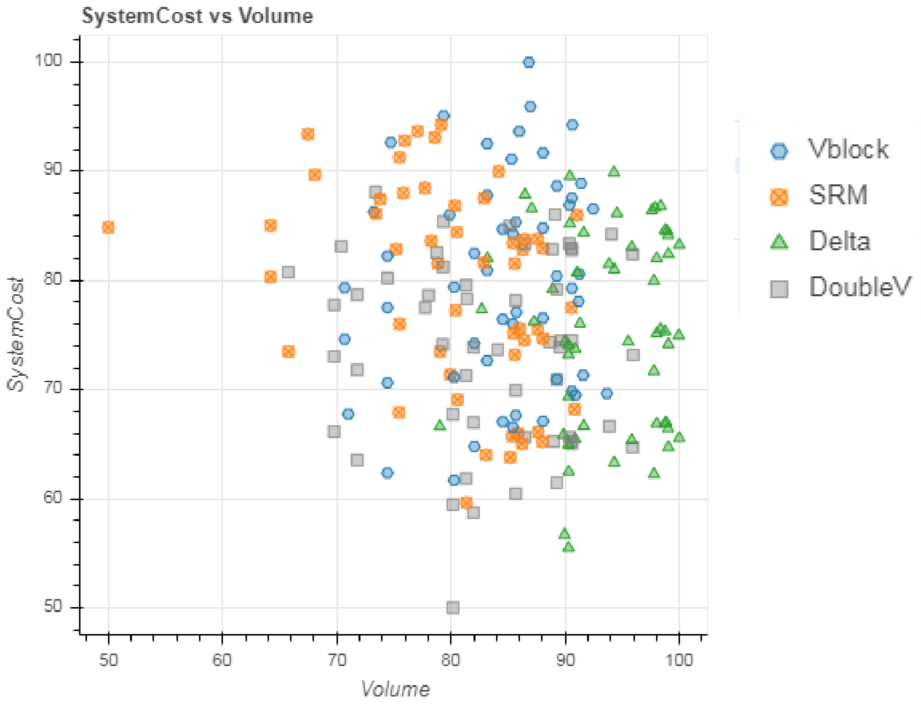

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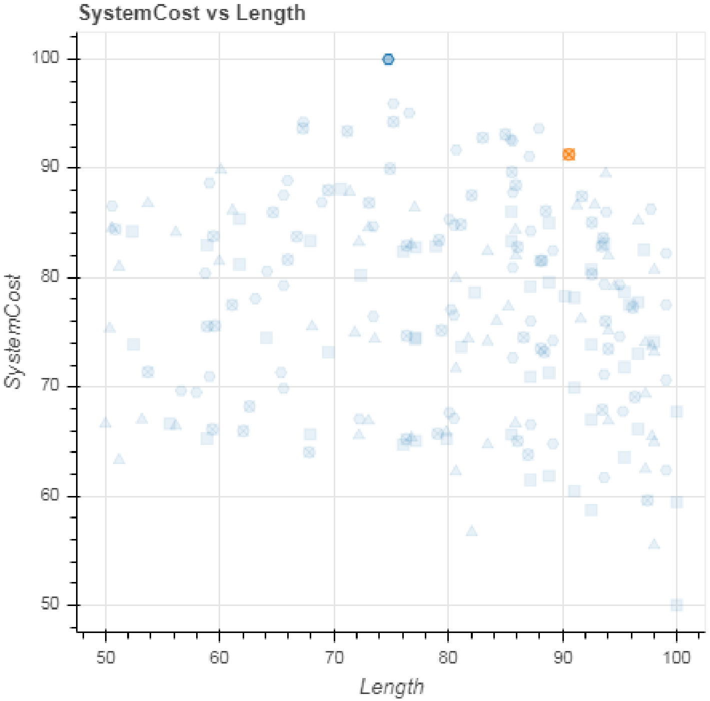
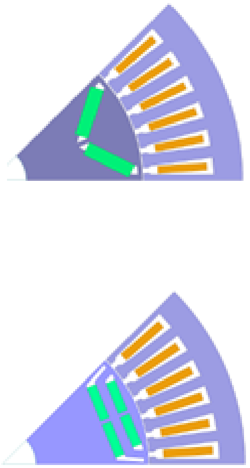
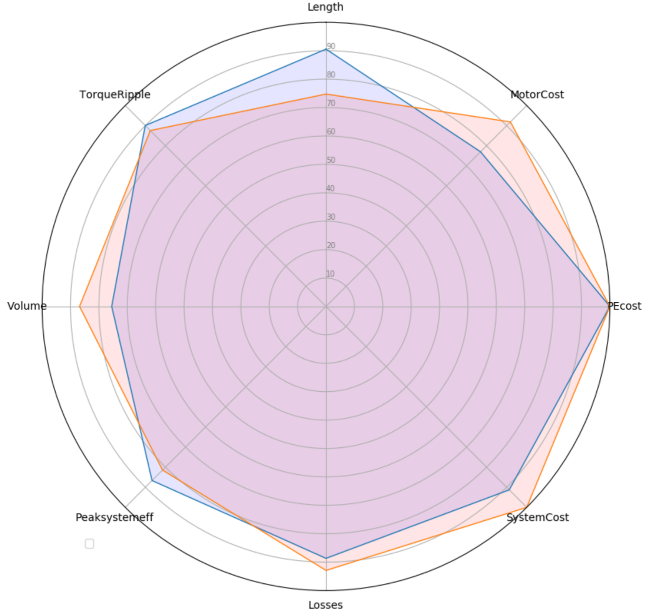




# System Sizing Tools

- **As shown in the previous slides the tool offers the ability to generate a vast number of solutions using high-fidelity analysis.**

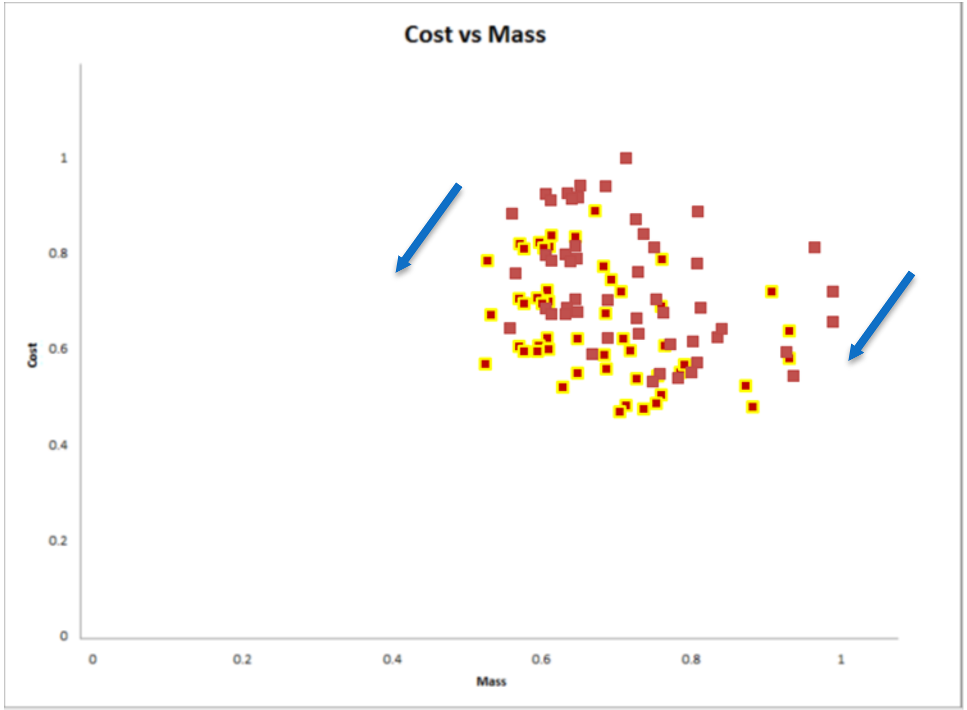
- **It is also possible to assess the real-world impact of any small change in any component of the system.**

- **Examples of changes that can be assessed include:**
  - Impact on noise of micro-geometrical variations in rotor and stator designs.
  - Impact on efficiency of conductor coating material and thickness.
  - Impact on available power electronic current for different coolant temperatures and flow-rates.
  - Impact on cost for different winding processes.

- **These changes can also have a positive impact on the vehicle as a whole:**
  - Higher system efficiencies leading to smaller, cheaper, lighter battery packs.
  - Lower NVH leading to improved passenger comfort.

# Magnet Wire Coating Example

- **Reduced motor length for the same performance leads to a lighter, lower cost machine:**
  - Up to 10% reduction in electric machine length.
  - Up to 6% reduction in electric machine mass.
    - Improves vehicles dynamic performance.
    - Improves vehicle packaging opportunities.
    - Potential to reduce battery size.
  - Up to 10% reduction in electric machine cost (due to reduction in length).
    - Due to higher torque and power outputs of machine with alternative wire insulation.



# Concluding Remarks

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- **Customers often ask eDrive “what is the lowest cost electric traction system for our electric vehicle?”**
  - They are not concerned with what technology is used.
  - They need convincing that the system we propose is the lowest cost.
- **Traditional subjective methods come with a risk of “missing” the best solutions.**
  - Best guesses for geometry.
  - Past experience.
- **With our proprietary tool we can guarantee that the best solution is found objectively.**
  - Validated high-fidelity models analysed at every stage of the process.
  - All solutions are feasible, real-world systems.
- **Numerous customers have already benefited where eDrive have offered state of the art solutions that meet their requirements.**

# Upcoming Projects

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- **eDrive have secured government funding for a power electronics project on the IDP15 stream.**
  - 2 year project targeting improvements in system costs, efficiencies, and packaging.
  - 5 partners within industry.
  - The project addresses the Department for Transport ‘Road to Zero’ strategy.

- **Dubbed ASIT (Advanced Silicon Carbide Inverter Technology) the project intends to:**
  - Deliver a game-changing 140kVa (115kW) SiC miniaturised power module with integrated gate drivers.
  - Move from an initial TRL3 to TRL6.
  - Meet the APC 2025 long-term goal of a $3/kW and 50kW/kg inverter.

EDRIVE