Work Package 3.2

Optimization and Control Design

Team

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1 RF and 1 RA to start in March

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Work Package Aims

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Battery Prognostics and Estimation

- Identify and compare suitable techniques
- Understand constraints for implementation

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- Reduce ageing with system-level optimization
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Machine Prognostics and Diagnostics

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Key Achievements

Battery Prognostics & Estimation

- Three estimators for SoH, SoC and temperature
- Results on performance vs computational complexity

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- Linear parameter varying battery model with SoH and temperature dynamics
- Battery-supercapacitor powertrain sizing

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System optimization and control

- Linear parameter varying battery model with SoH and temperature dynamics
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Machine Prognostics & Diagnostics

- Simulated winding and out-of-balance faults

Key Achievements

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Three **conference papers**

Three **journal papers** (two under review)

A control **workshop** (Cranfield, November 2013)

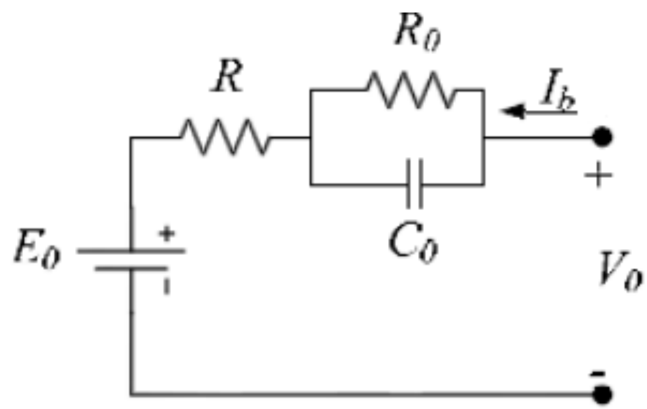
Battery Prognostics and Estimation

System optimization and control

Machine Prognostics and Diagnostics

Battery Model

- Linear Parameter-Varying



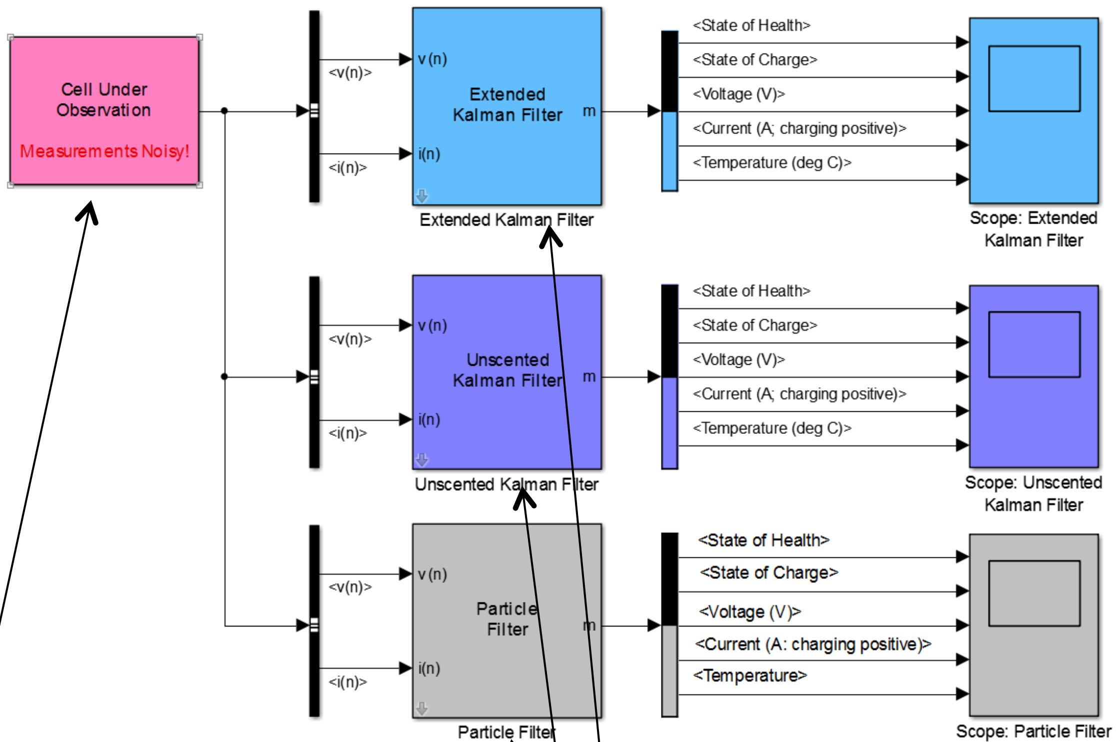
- State of charge:

$$\frac{d}{dt}(\mathrm{SOC}) = \frac{+i_b(t)}{3600\,k_C}$$

- State of health:

$$\frac{d}{dt}(\mathrm{SOH}) = \frac{-|i_b(t)|}{3600\,k_C \times 2N_{\mathrm{cycles}}}$$

Optimal Estimators

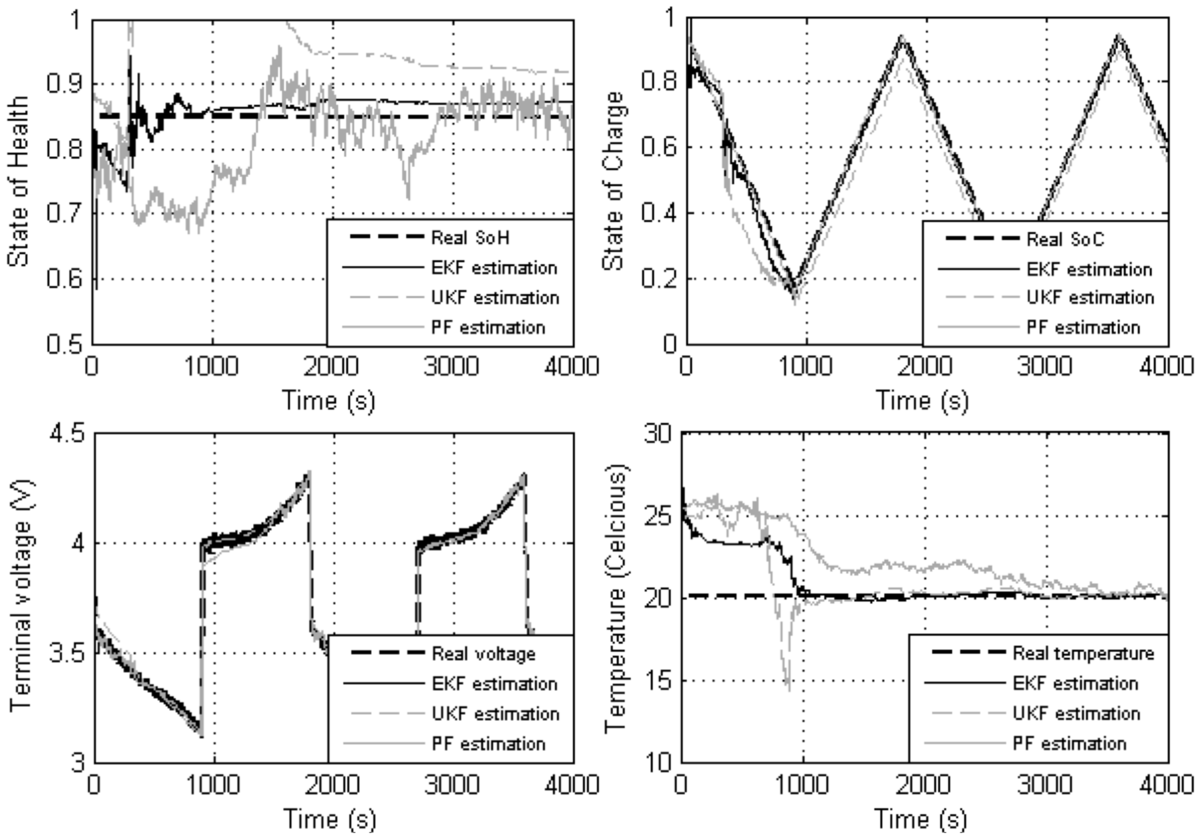


'real' cell with noise model

3 nonlinear optimal **estimators**

compare **results**

Estimation Performance Results



Estimation Complexity Results

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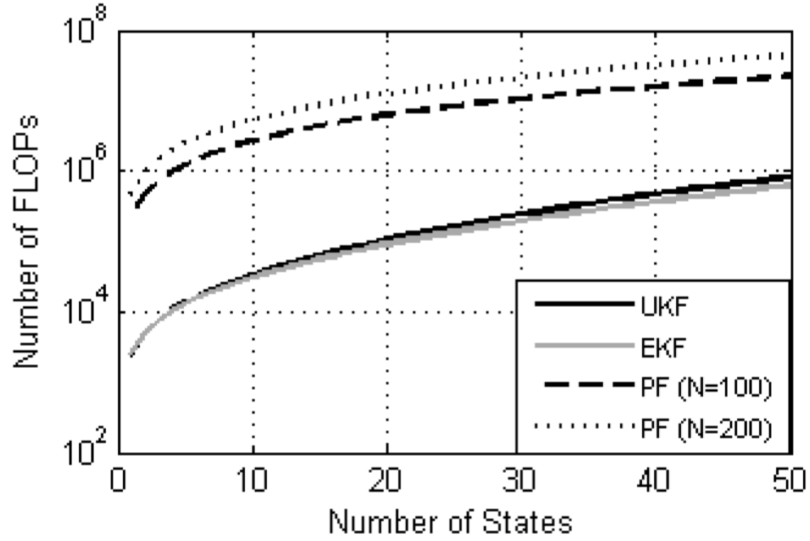
	EKF	UKF	PF
Time for one iteration (s)	0.0017	0.0041	0.0599
Proportion of execution time	1x	2.4x	35.2x



Estimation conclusion

What we've learned

- We can (in principle) estimate SOH and parameters
- Trade-offs between accuracy and complexity

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- Compare to high fidelity models or data

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What we need

- Validation data
- Models of ageing

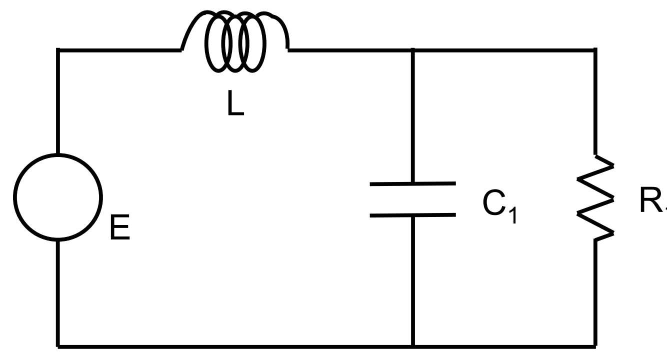
Battery Prognostics and Estimation

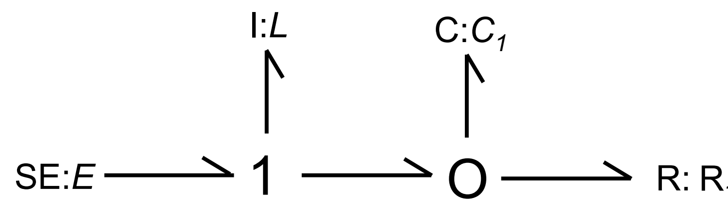
System optimization and control

Machine Prognostics and Diagnostics

Modeling – Bond graphs

- Energy based modeling
- Describes power interchange between systems as **effort** and **flow**
- Multidisciplinary





Modeling – Bond graphs

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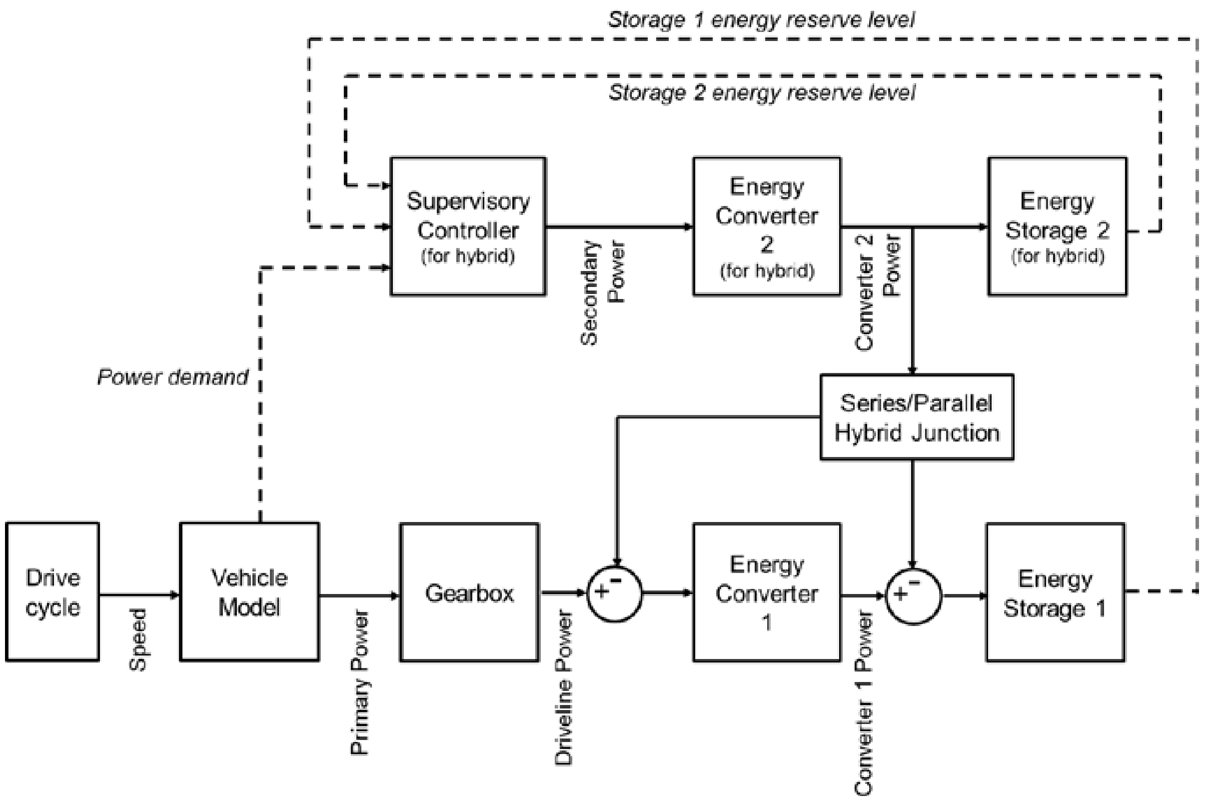
Example - modular powertrain structure



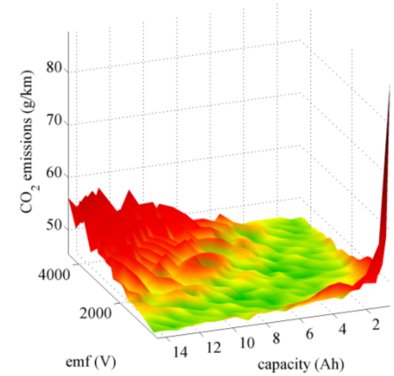
Battery Sizing

How does battery size affect the following?

- CO2 emissions
- Battery cost – per km of useful life.
- Lifespan

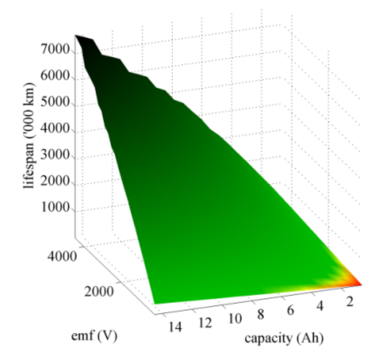
Battery Sizing

- If battery is **too small => less efficient**

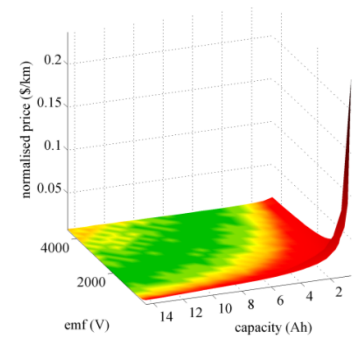


- Weight is only important when **very** large

- Low **CO2 emissions & good value** go together

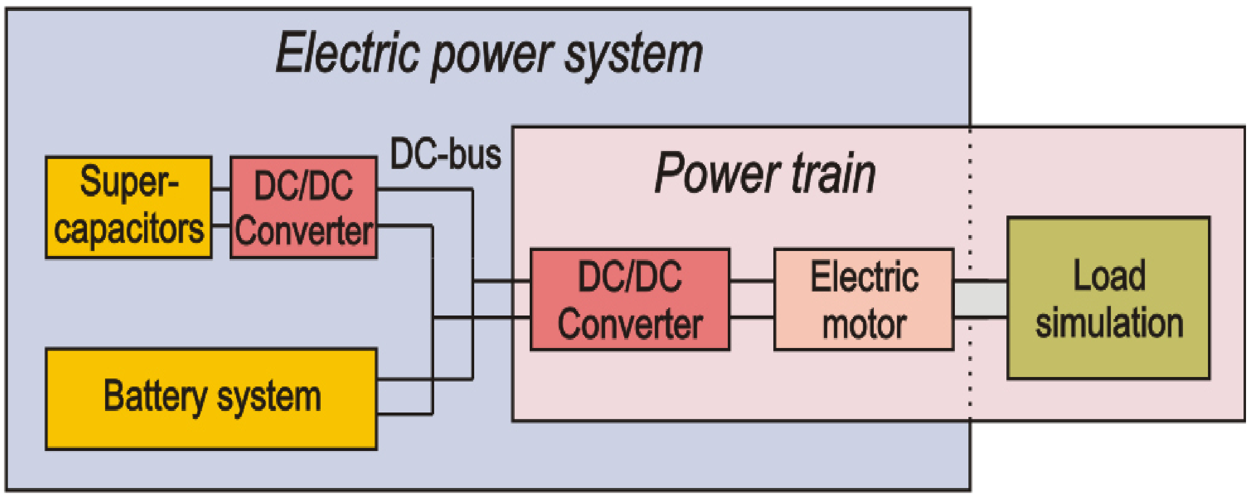


- Depends on our **assumptions**!



With Parallel Supercapacitors

Could supercaps help?



With Parallel Supercapacitors

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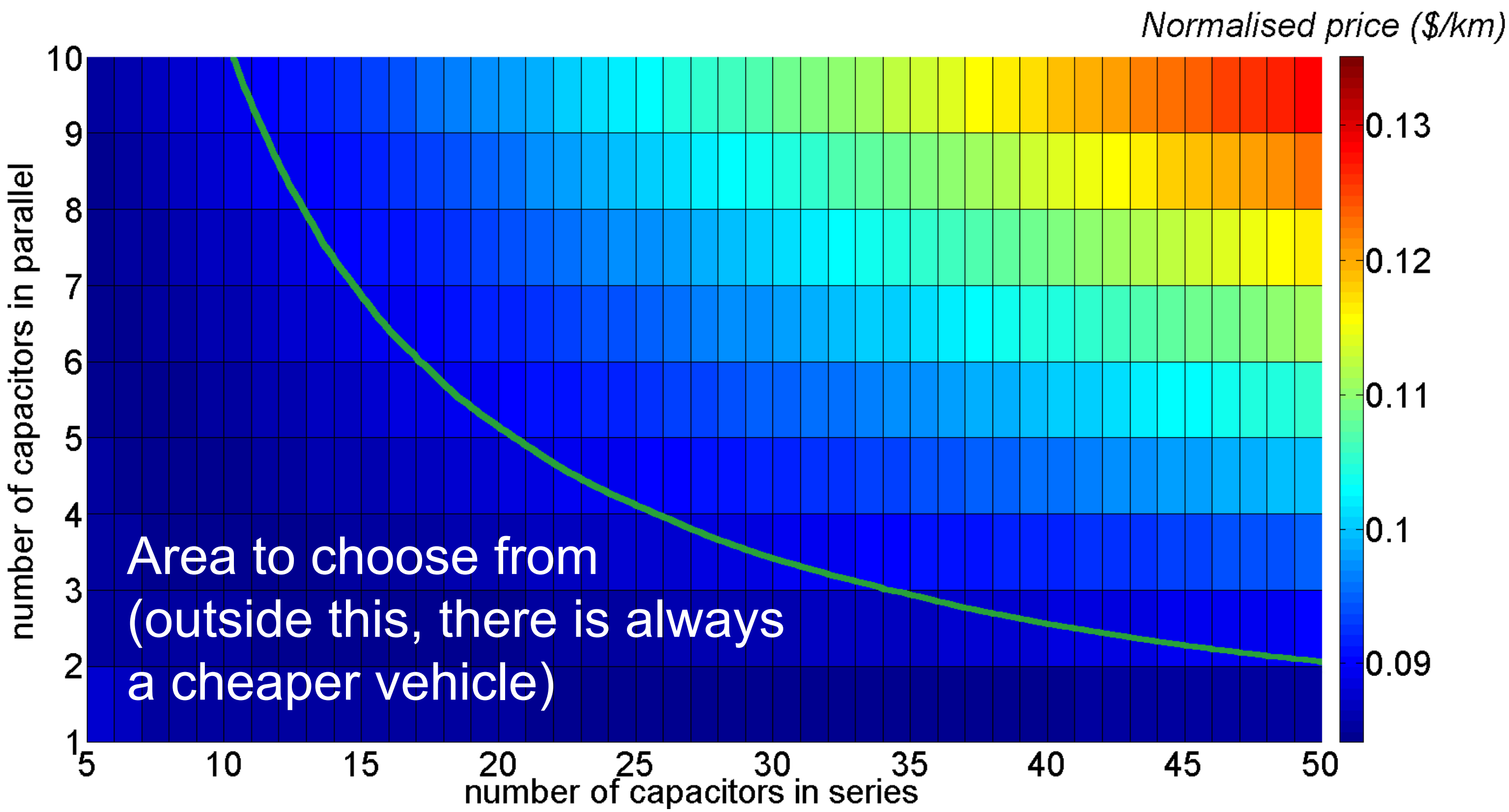
Price per km



With Parallel Supercapacitors

With 4 x 23 supercapacitor array (example)

- Absolute cost: $1600 more
- CO2 emissions only slightly worse
- Battery lifespan 20 000 km better

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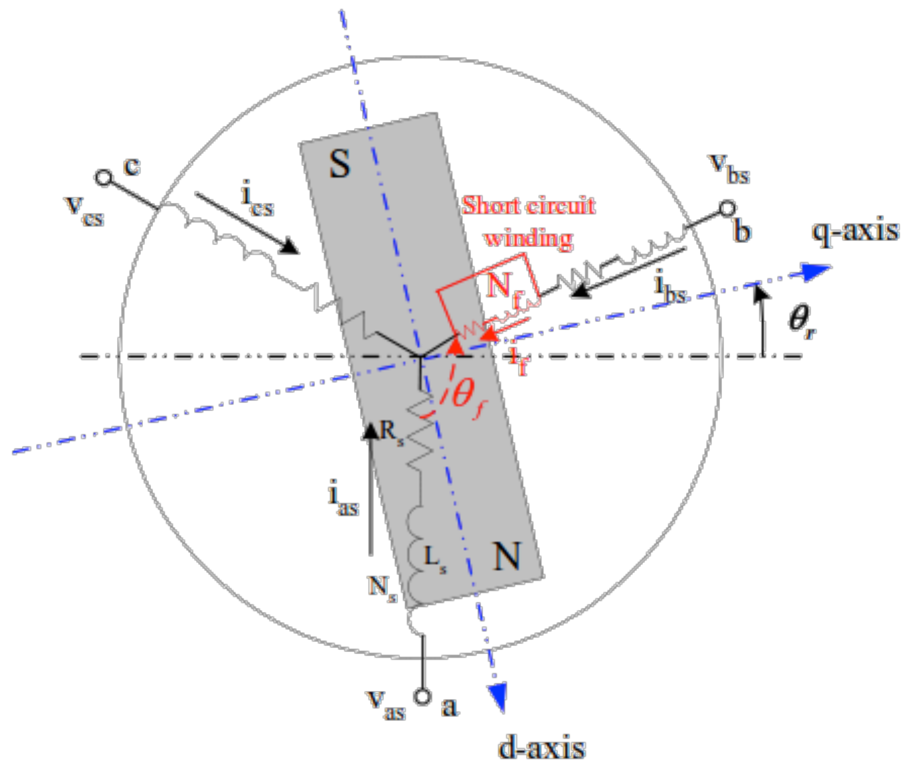
Machine Prognostics and Diagnostics

Electric machine degradation

Faults we are considering

Stator faults – opening/shorting of stator windings

- can be one winding or several



Electric machine degradation

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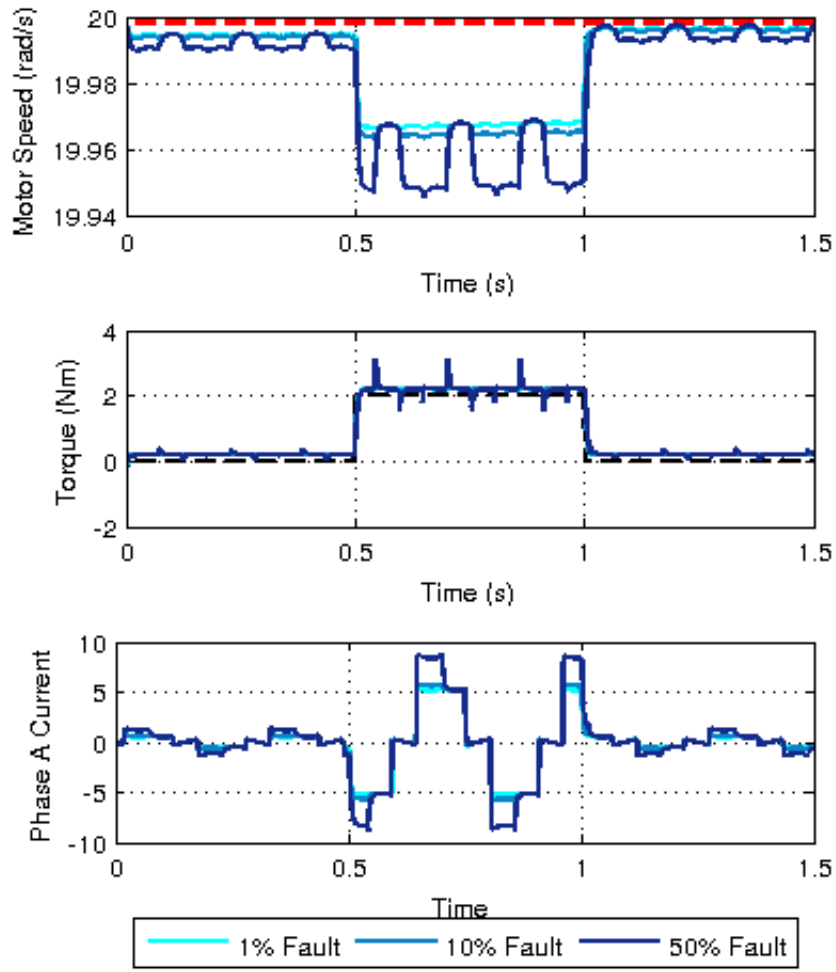
What we have learned

• Short-circuits produce time-domain patterns we can recognize



Electric machine degradation

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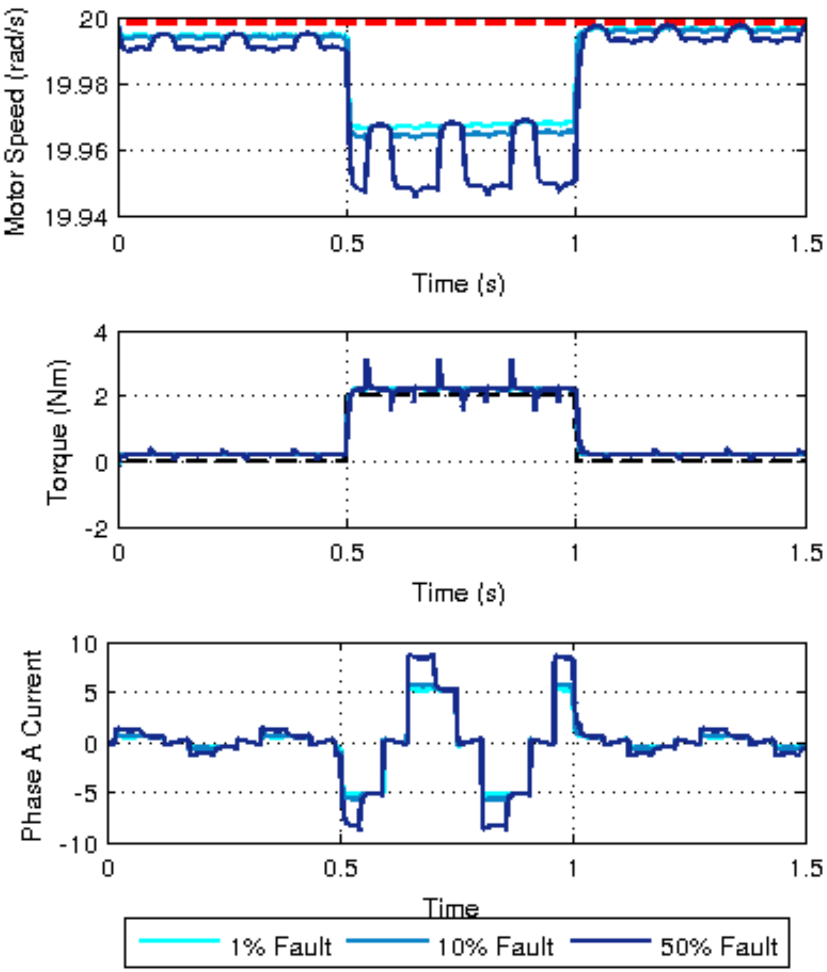
What we still need to do

• Analyse frequency signature
• Determine how faults and aging relate



Electric machine degradation

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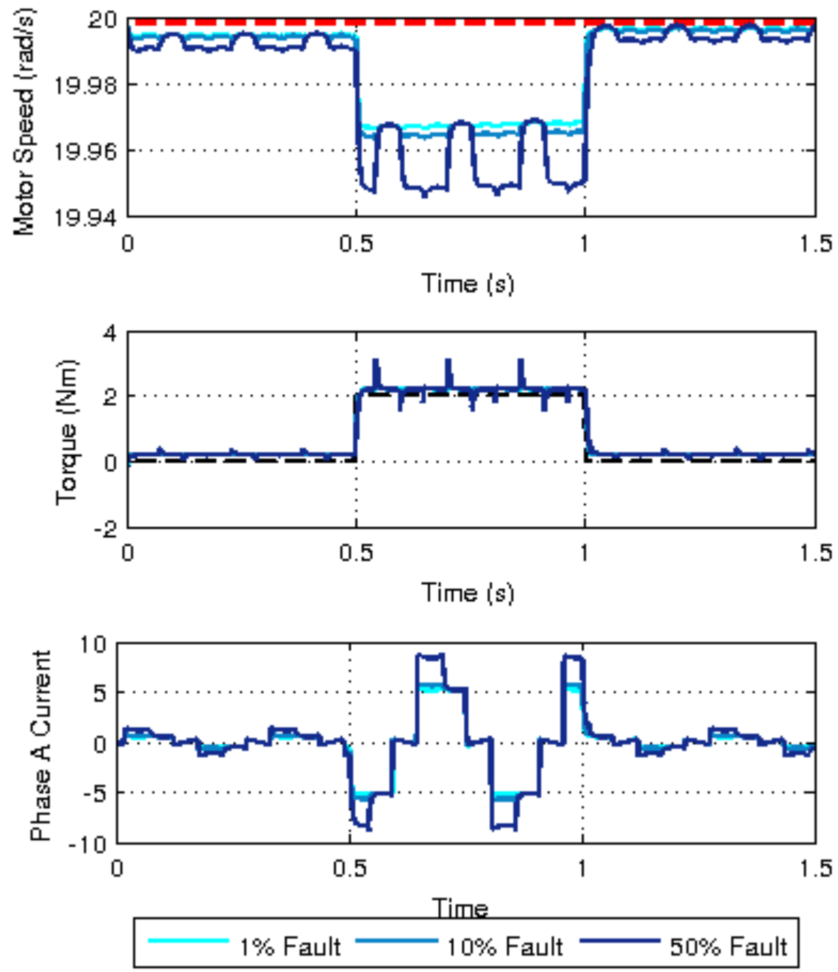
What we need
• Theory of how faults relate to aging
• Access to training data
• Experimental validation of fault modes



Moving forward

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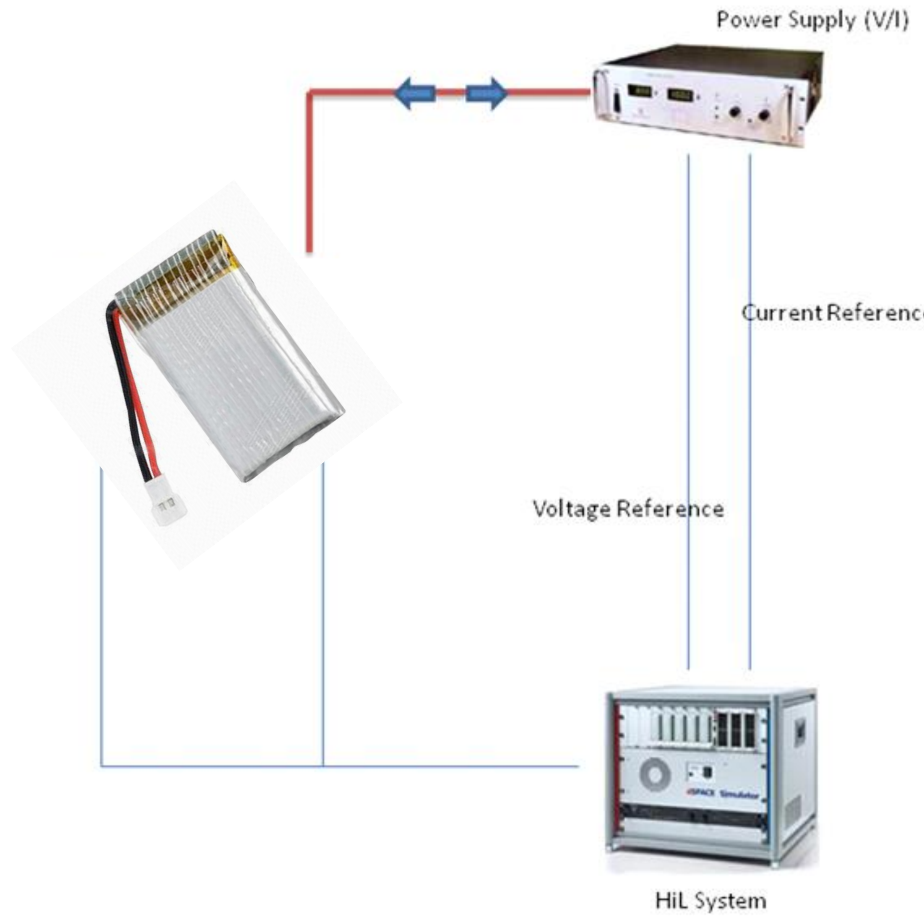
HIL implementation

- Export algorithms
- Model/simulate ageing?
- Tests with a real cell and/or motor



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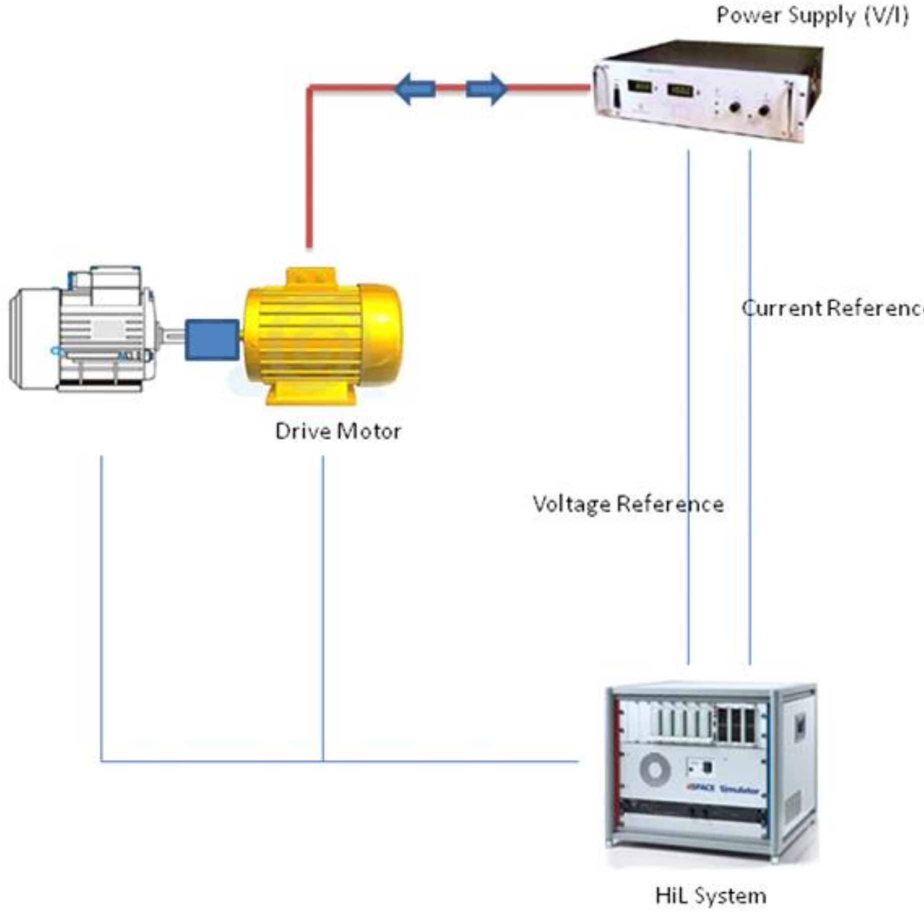

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Thank you

Coventry University | Cranfield University | Imperial College London | Loughborough University | University of Oxford | The University Of Sheffield.