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# Virtual Platform for NRMM hybridization research

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ECV Final Seminar & Nordic Electric Bus Initiatives 2

# The Background



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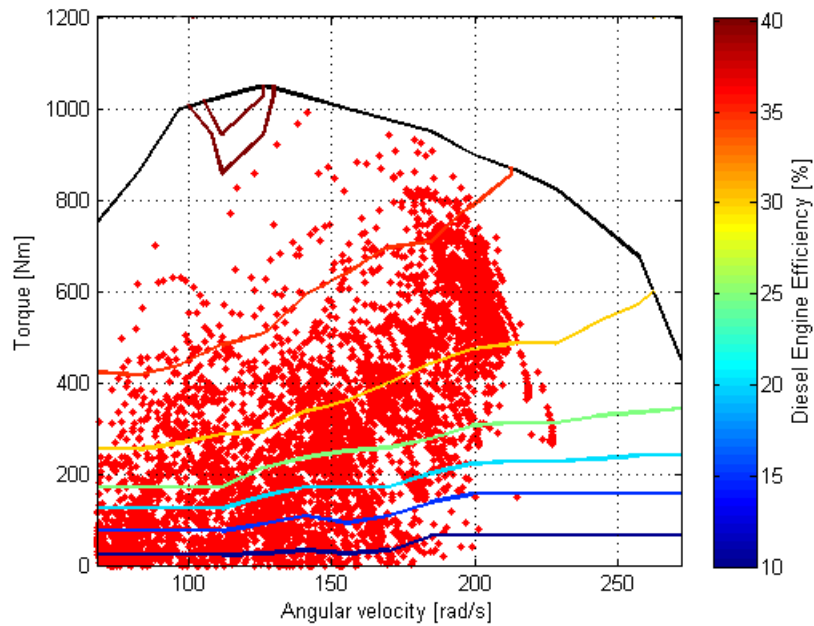
- Hybridization has been a trend in the past few decades, especially in automotive industry
- NRMM manufacturers are picking up the pace, as hybrid working machines are entering the market
- Series hybridization has shown to have great impact on the fuel economy of the machine
  - Separating the power production and consumption mechanically
  - Downsizing the diesel
  - Optimal operational point

# Series Hybridization

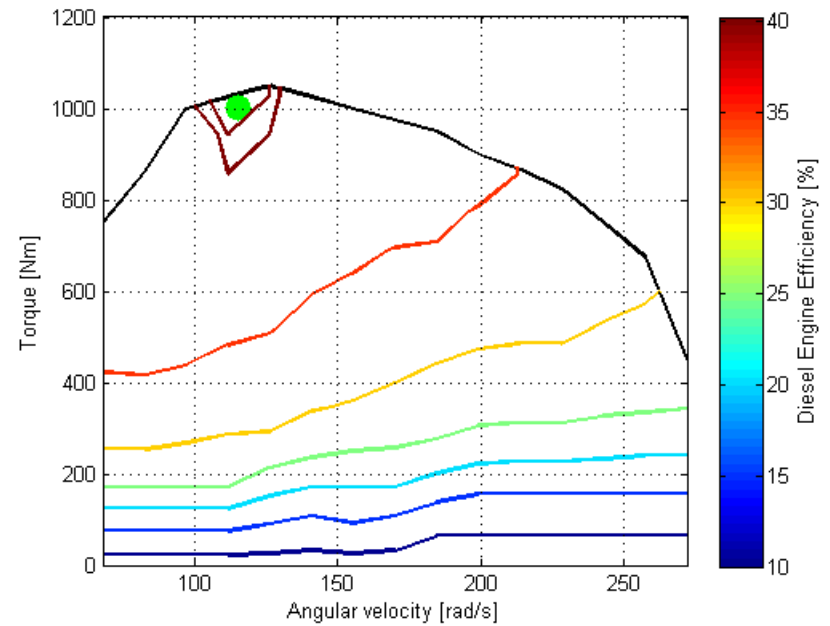


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To turn this...



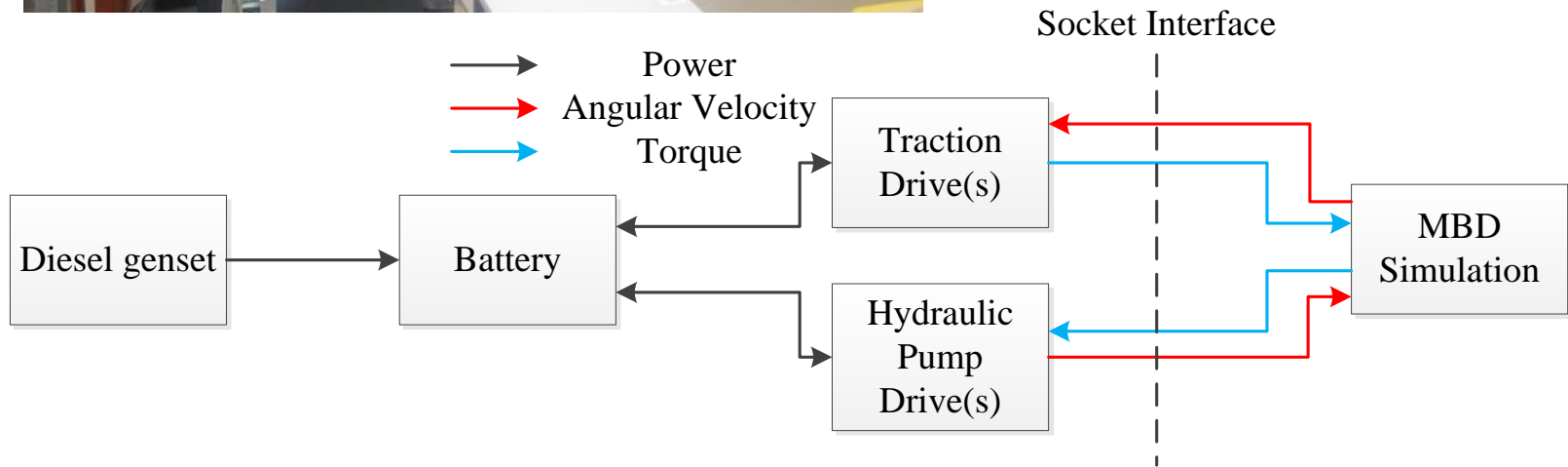
...into this!



# The Co-simulation Setup



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# Research and Results

# LH410 Research



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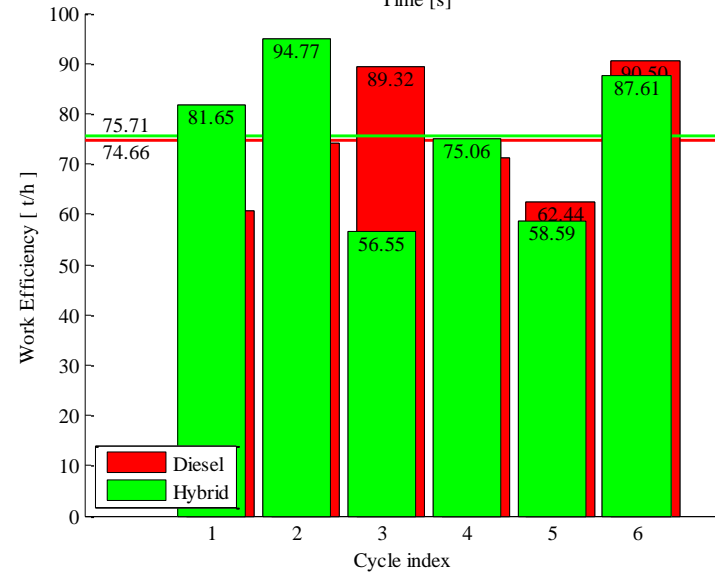
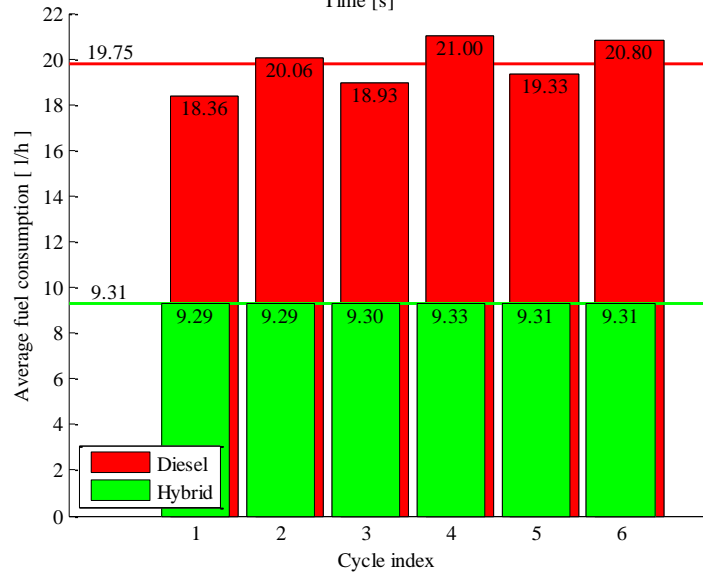
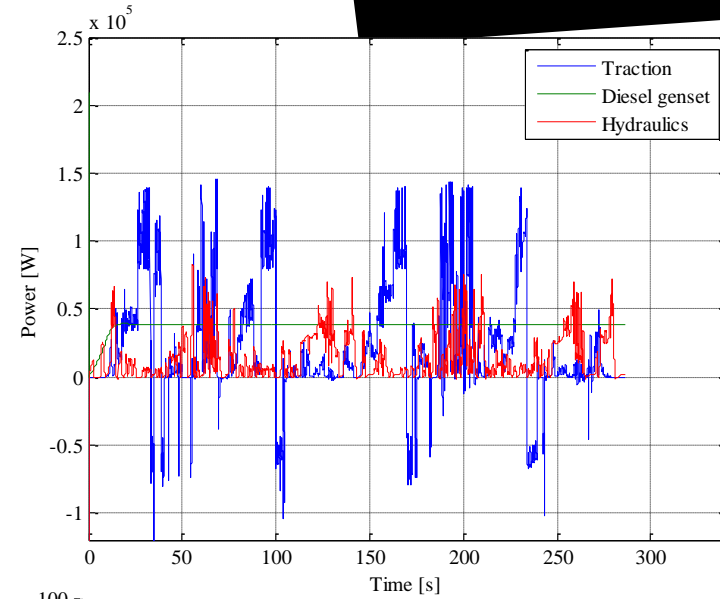
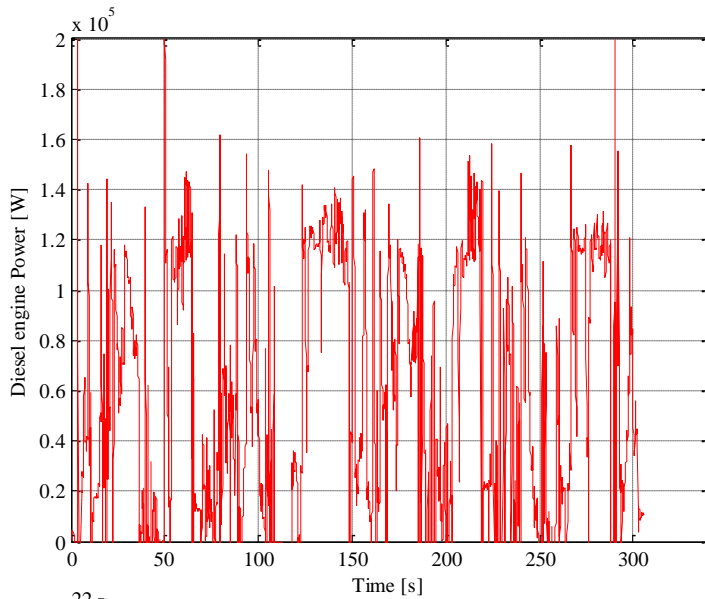
- Purely virtual test was driven to analyze series hybridization effects on a 26-ton underground loader
- Professional driver was used to drive both unhybridized and hybridized variants on two route lengths
- Fuel consumption, work efficiency and energy efficiency were analyzed
- Realism and overall feel of the setup was also solicited
- Existing mechanical driveline was driven by one PMSM, hydraulic system with another
- 36 kWh Lithium battery pack



# LH410 Results



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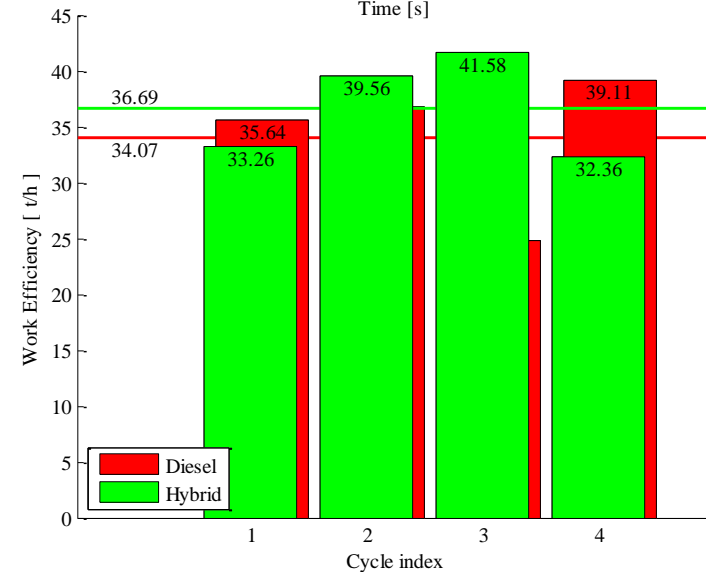
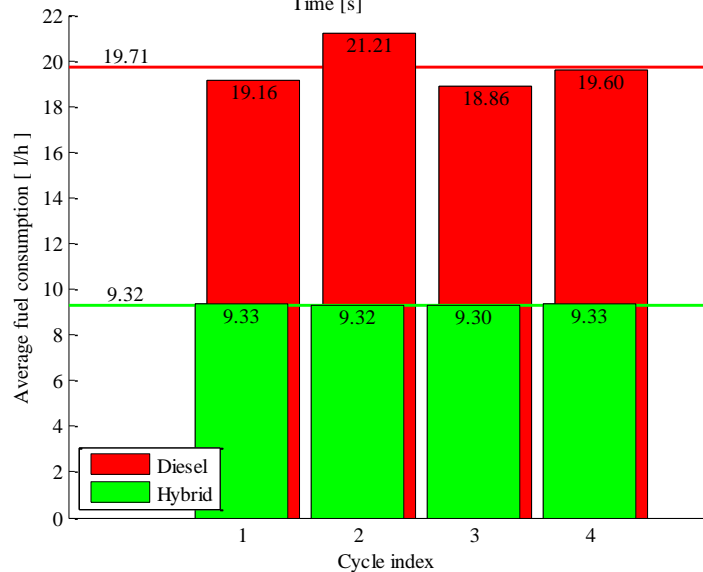
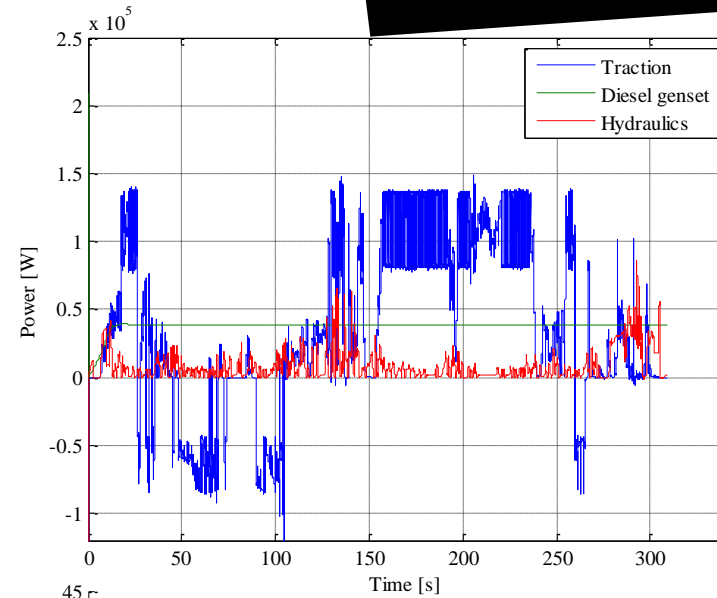
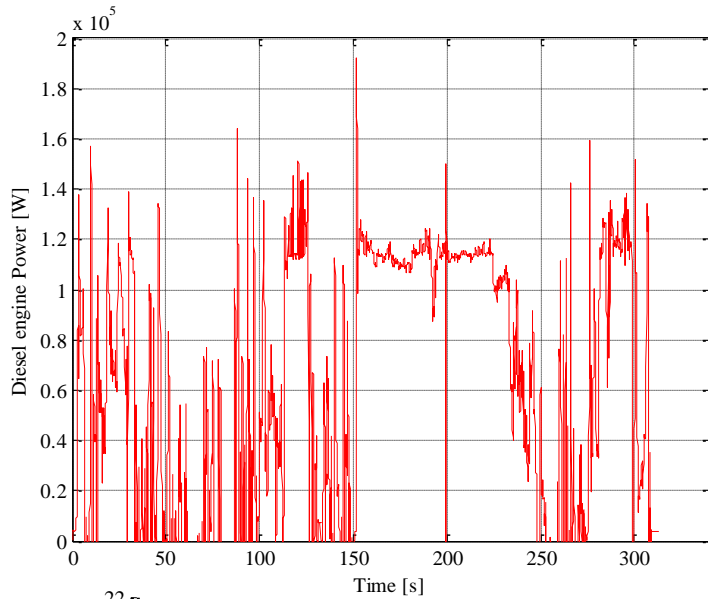




# LH410 Results



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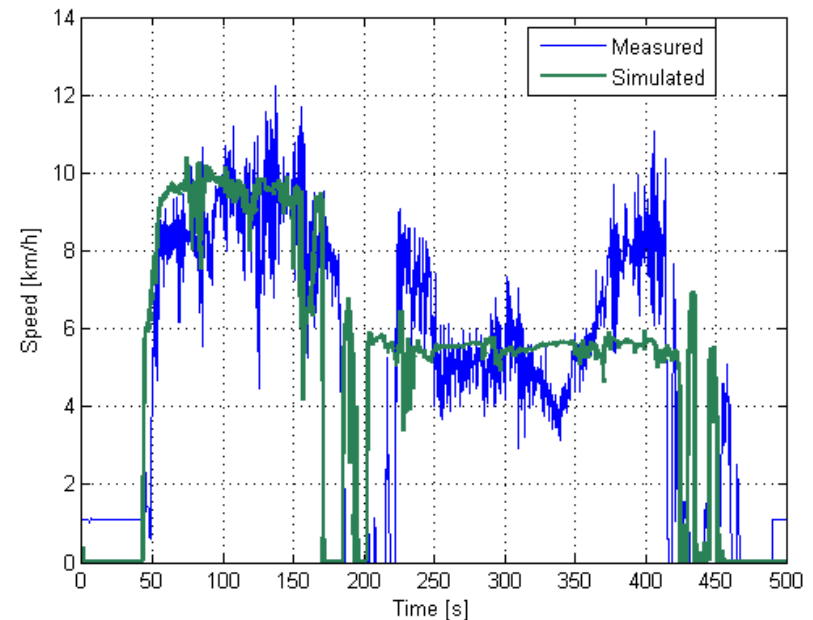


# EJC90 Research



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- Tubridi Project case machine was also an underground loader – 14-ton EJC90
- Verification of the virtual model of the unhybridized loader could be done against a recorded test cycle
- Simulated fuel consumption was within 5% margin of error compared to the drive cycle
  - Same work
  - Same timespan



# EJC90 Research



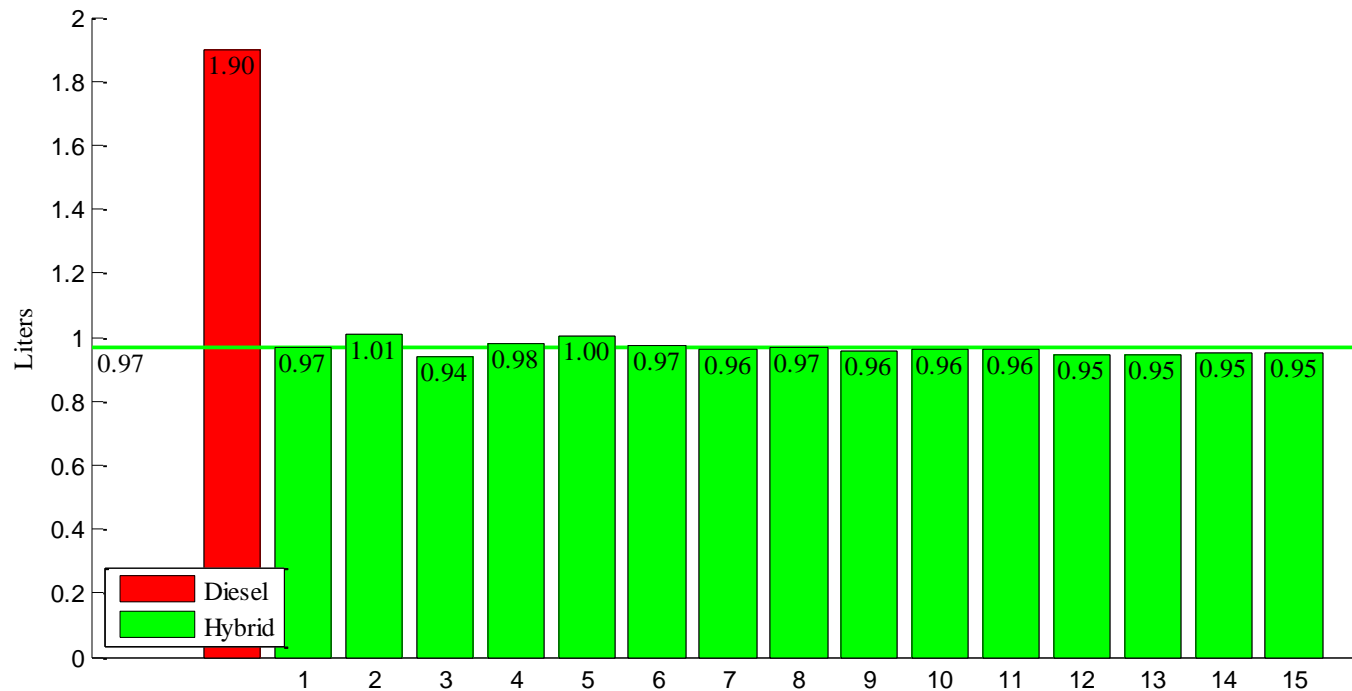
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- Hybridization of the virtual EJC90 was done according to the real-life counterpart in Aalto
  - Two induction motors driving the rear and front shafts
    - 4-speed gearbox in the rear shaft
    - Belt gears for both traction motors
    - Final reduction gears
  - 14.5 kWh Li-ion battery pack
  - 2-liter VW diesel engine
    - driven at 31.5 kW power – close to peak efficiency
- 15 cycles were driven with the virtual EJC90 hybrid with the same work done as with the unhybridized, and with the same duration of the cycle

# EJC90 Results



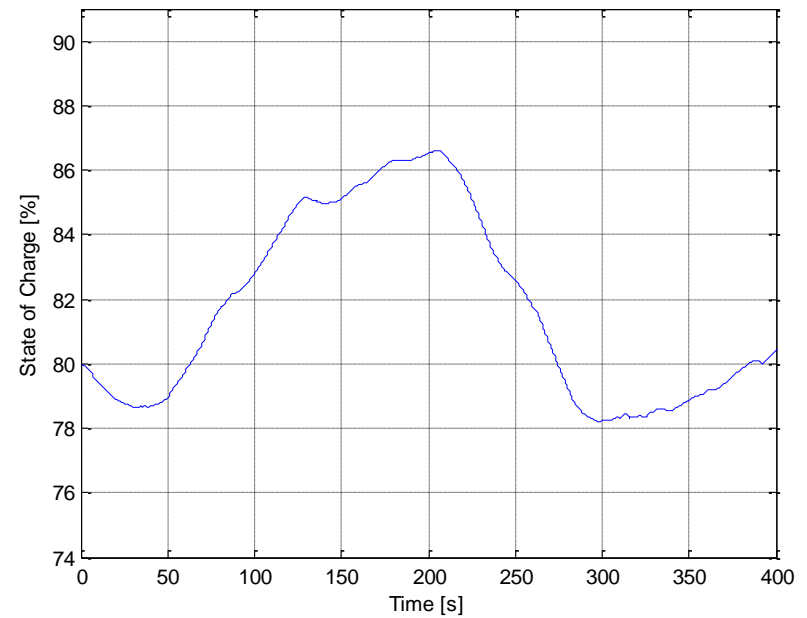
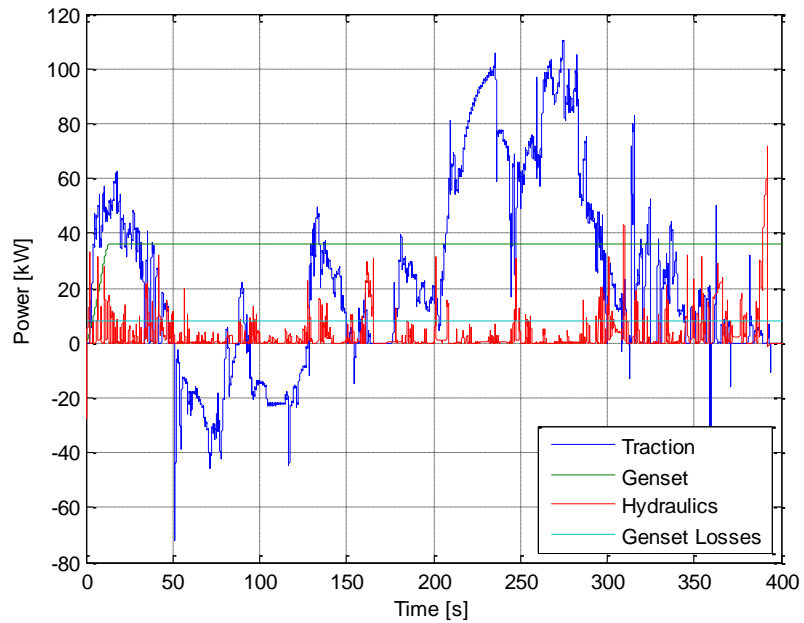
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# EJC90 Results



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# Conclusions



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- Series hybridization can reduce the fuel consumption of heavy duty mobile working machinery as much as 50%
  - Optimal operational point for the diesel
    - No dynamic loads
  - Possibility for regenerative braking
- Co-simulation platform enables the machine manufacturers to rapidly model, iterate and analyze new variants as well as new machines
  - Simulation platform reacts to all changes, for example in the driveline
  - Numerical parameters of the machine model or – for example – driveline structure can be altered within minutes

# Conclusions



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- Main challenge with the system is repeatability
  - For the most part, all cycles must be driven individually
  - Boundary conditions determine the similarity of cycles
    - In the presented research, these boundary conditions are same work done in the same timespan
    - What kind of boundary conditions are sufficient for high enough accuracy?



Thank you for your attention!  
Questions?

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