A Detailed DOE Study for Concept Level Battery Electric Vehicle Energy Dimensioning

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Introduction

➢ Energy dimensioning
  • Battery Capacity
  • Motor Power

➢ Early stage system model based design iterations
  • Reduced cost of product development
  • Robust products

A DOE study can be helpful to

1. Understand variations in vehicle performance over a range of powertrain sizes
2. Narrow down to feasible designs
Objective

Perform Design of Experiments (DOE) to analyse

Effects of the following factors:
- Battery Capacity (Ah rating)
- Motor Power (kW rating)
- Final Drive Ratio

To study the following responses:
- Range of Electric Vehicle over NEDC drive cycle
- Acceleration Performance (0-100 kmph time)
Objective

Multi Objective Pareto Optimization has been performed to:

- Maximize vehicle range
- Minimize acceleration time

- Performed to identify the optimal design points across the design space
Assumptions

➢ Battery Internal Resistance maps for Charge and Discharge cycles have been considered constant over the range of battery capacities

➢ Constant auxiliary load assumed for the entire drive cycle

➢ Motor efficiency was assumed to be constant throughout its operating range

➢ Standard atmospheric conditions where applicable
Model Setup:

- Battery Controller
- Brake Controller
- Driver Controls
- Vehicle
- DC-DC Converter
- Battery Pack
- Traction Motor
- Aux 12 V
Vehicle sub-assembly:

- Tire FR
- Brake-1
  - bs4
- Axles
- Environment
- Battery Mass
  - bs3
  - Brake-4
- Axle RR
- ToPart_6
- ToPart_14
- FromPart_11
- Vehicle Body
- Differential
  - bs2
  - Brake-3
  - Axle RL
  - Tires
  - Tire-FL
  - Axle FL
  - Brake-2
  - bs1
DOE Setup

➢ Latin Hypercube with 1000 Experiments

Setting up bounds

Generated DOE Configurations
Results: Relative Factor Effects for Vehicle Range

- **Vehicle Range (km)**
  - Battery Capacity
  - Motor Power
  - FDR

**Graph Details**
- Vertical axis: Vehicle Range (km)
- Horizontal axis: Relative Factor Effects
- Graph shows the impact of Battery Capacity, Motor Power, and FDR on Vehicle Range.
Results: Relative Factor Effects for Acceleration time

- Battery Capacity
- Motor Power
- FDR

Relative Factor Effects for Acceleration time (sec)
Results: Acceleration time - Individual Factor Effect

- Increase in battery pack capacity results in increase of the weight of a battery pack
- This leads to increase in the acceleration time
Results: Acceleration time - Individual Factor Effect

- For a fixed required speed, the Tractive effort will remain constant irrespective of the reduction ratio.
- Thus, FDR does not have a significant impact on the acceleration time.
Results: Vehicle Range - Metamodel quality

- Predicted Distance vs. Observed
- Upper %Err
- Lower %Err
- 0% Err
Results: Acceleration time - Metamodel quality
Multi Objective Optimization: Pareto Front

107 optimized design points identified by Pareto optimization

Region of interest
Design Space

40 optimized design points identified in our region of interest
Conclusions

➢ Multi objective Pareto Optimization was performed to arrive at the best possible design configurations for maximizing vehicle range and minimizing the acceleration time from 0-100 kmph
➢ 40 design configurations were identified which can be used for further analysis
➢ Distributed execution feature in GT-SUITE efficiently utilizes computer resources for quick exploration of multidimensional design space
➢ Using multiple solvers and cores, DOE run time was reduced to about 6 hours, Pareto optimization only took 30 seconds.
Future Scope

- Effect of transient auxiliary loads can be studied
- Effect of transient battery cell and motor characteristics can also be studied
- Further parameters like vehicle weight, coefficient of drag, frontal area can be used for optimization using the same methodology
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Questions?
Thank you

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