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Computational Optimization of Battery Grid for Efficiency and Performance Improvement

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Great: Develop Great Technology.

Growth:Grow into a Billion Dollar Company by 2020.

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Introduction

- Battery is the critical system used in automobile, renewable energy, medical devices and mobile phones.

- Lead acid battery is considered and computational optimisation is made for its efficiency and performance improvement.

Lead acid battery

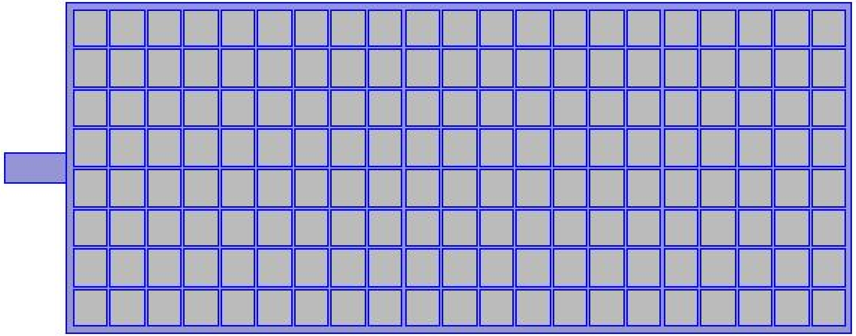
- Lead Acid battery, although a two hundred years old technology, is the workhorse of the industry.

- Battery grid is the precursor for the active material and current distribution in lead acid electrochemical cell.

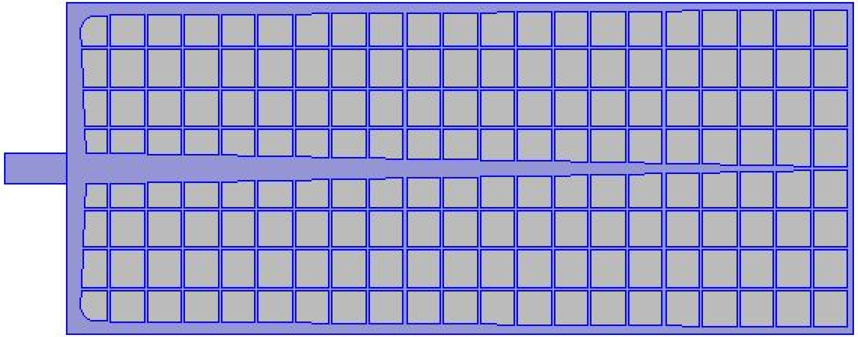
- Study for optimal configuration of the grid is critical for minimising ohmic drop,uniform current distribution and for more reaction sites.
- Current density is correlated to increased corrosion resistance and life cycle time.

Standard and new grid

Case 1: Standard grid



Case 2: New grid design



CEM Formulation

- The governing transport equations for electro chemistry of lead-acid battery is due to migration, diffusion and convection molar flux of charged species(j).

- For the grid design, the Laplace eqs can be used to model ionic transport performance.

- Appropriate Electrode equilibrium potential is used.

- COMSOL Primary Current Distribution interface for the battery is used for the CEM simulations.

$$N_j = -z_j \mu_j F C_j \nabla \emptyset - D_j \nabla C_j + C_j v$$

$$\nabla_i = \sigma \nabla^2 \emptyset$$

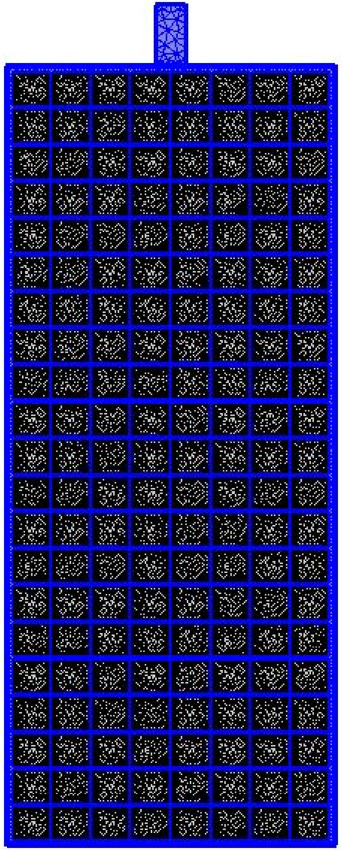
$$\nabla^2 \emptyset = 0$$

$$\eta = E - E_e - \emptyset$$

N_j - iconic flow
Z_j - charge
μ_j - ionic electrochemical mobility
F - Faraday's constant
c_j - concentration
∇ - Differential operator
Φ - Electrostatic potential
D_j - diffusion coefficient

Boundary Conditions

- A discharge current of 100 A is applied to the end of the lug.
- The primary current condition, relating the electrolyte and electrode potentials is set to the equilibrium potential of 1.7 V
- The potential in the electrolyte is set to zero at the external boundary that is parallel to the grid.

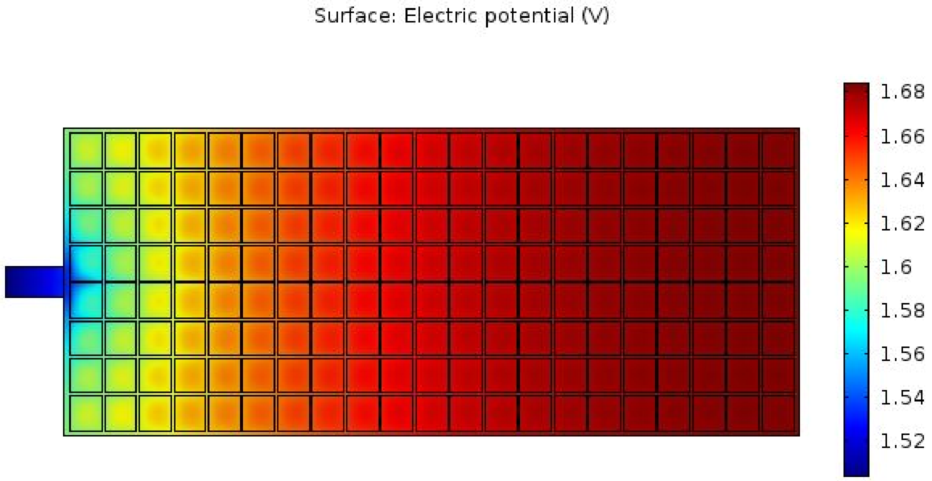


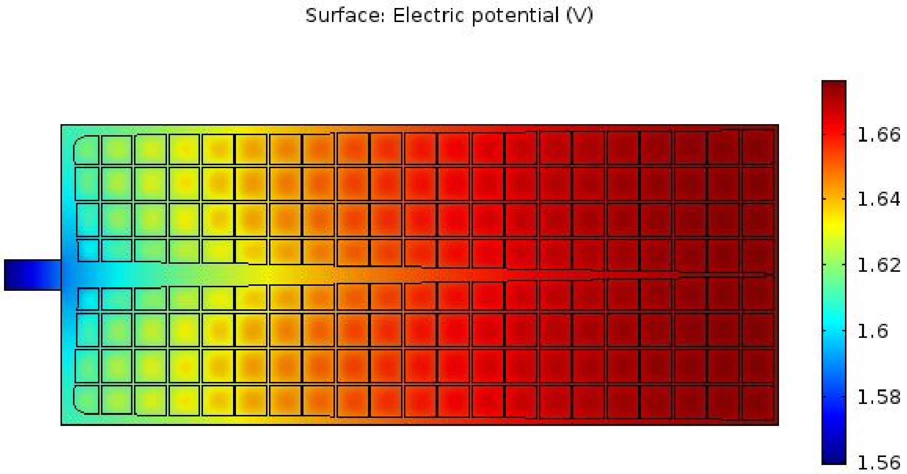
Simulation Results

Standard (case 1) Vs New Design (case 2)

1. Electric Potential (V)
2. Electrolyte Potential (V)
3. Electrode Current Density (A/m^2)
4. Total Power Dissipation Density (W/m^3)

Electric Potential

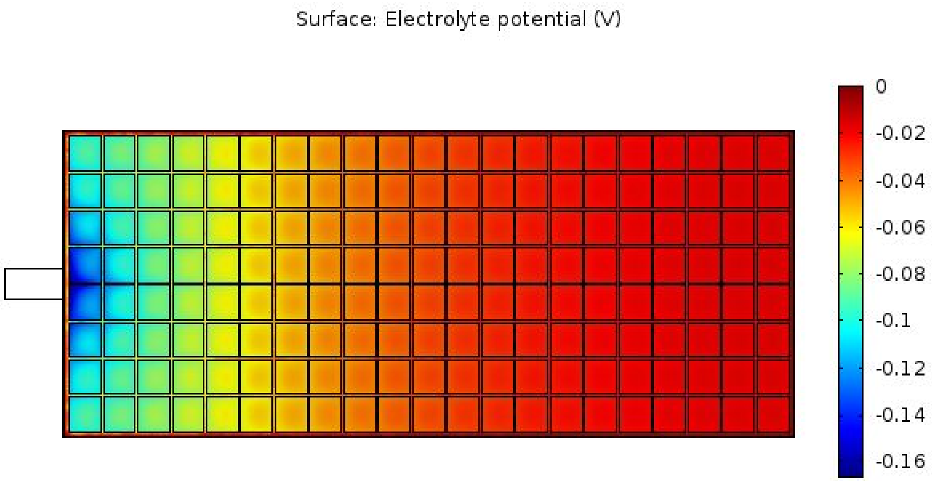


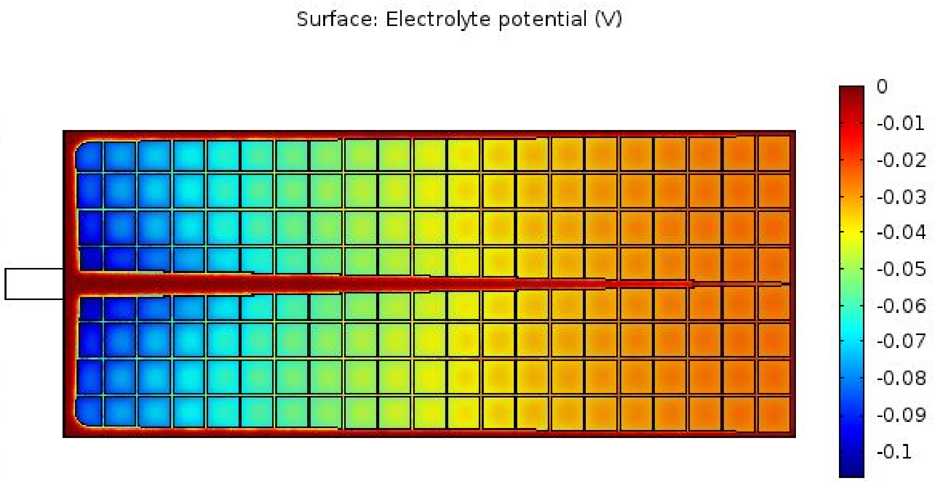


Contour plots of electric Potential (V) of the standard grid and new optimized grid with the minimum, maximum values and range.

Electric potential (V)	Max	Min	Range
CASE 1	1.68	1.52	0.16
CASE 2	1.66	1.56	0.10

Electrolyte Potential

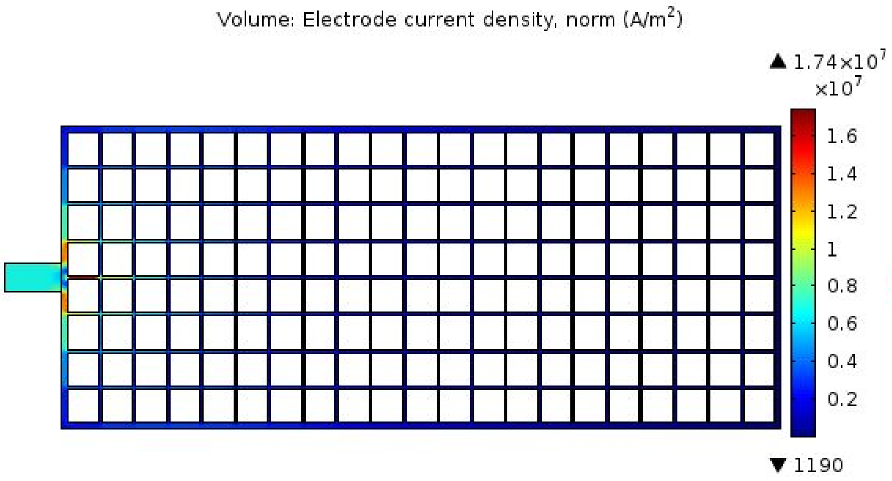


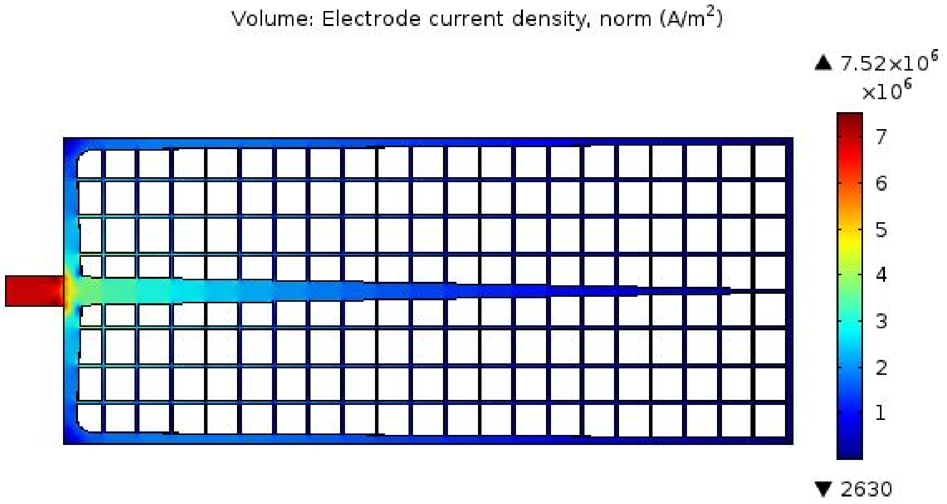


Contour plots of Electrolyte potential(V) of the standard grid and new optimized grid with the minimum, maximum values and range.

Electrolyte potential(V)	Range
CASE 1	-0.16
CASE 2	-0.1

Electrode Current density

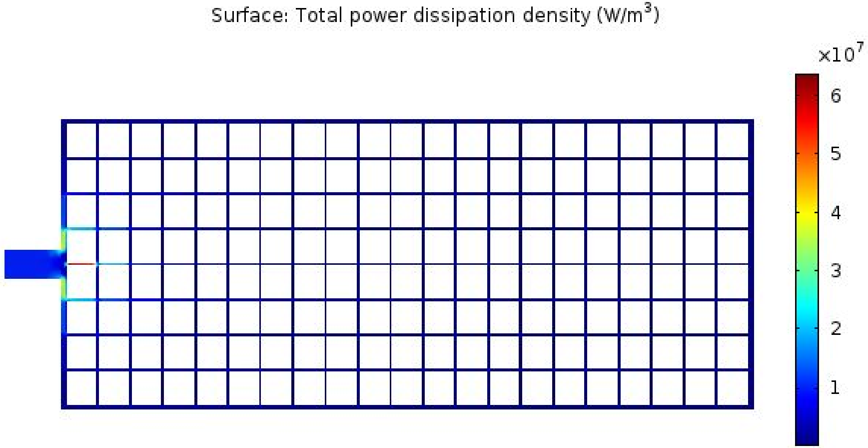


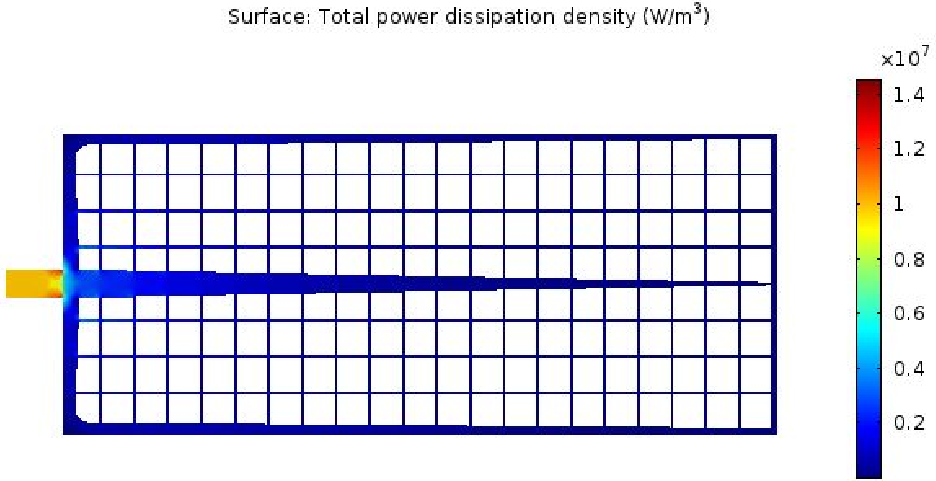


Contour plots of Electrode current density(A/m^2) of standard and new grid with the minimum, maximum values and range. **Reduced ECD 57 %**

ECD (A/m^2)	Max	Min	Range
CASE 1	1.74E+07	1190	1.74E+07
CASE 2	7.52E+06	2630	7.52E+06

Total power dissipation density





Contour plots of total power dissipation density(W/m^3) of the standard grid and new optimized grid with the minimum, maximum values and range **76% reduced**

TPDD(W/m³)	Max	Min	Range
CASE 1	6E+07	1	59999999
CASE 2	1.4E+07	0.2	13999999.8

Summary of results

- No significant changes in the electrode and electrolyte electric potential.
- By comparing the standard and new grid, the optimized grid shows 57 % reduction in electrode current density(A/m^2)
- The optimized grid shows 77 % reduction in total power dissipation density(W/m^3)

Electrode Current Density(A/m^2)			
ECD (A/m^2)	**Max**	**Min**	**Range**
Case 1	1.74E+07	1190	1.74E+07
Case 2	7.52E+06	2630	7.52E+06
Reduction	**57%**		

Total Power Dissipation Density(W/m^3)			
TPDD(W/m^3)	**Max**	**Min**	**Range**
Case 1	6E+07	1	59999999
Case 2	1.4E+07	0.2	13999999.8
Reduction	**77%**		

Conclusion

- The optimized grid shows significant improvement in current density distribution and total power density distribution for overall improvement battery performance

- The computational electromagnetics (CEM) based battery performance modelling method shows insight into battery physics for performance optimization.

- These investigations highlight the potential of CEM and electrochemistry simulations for innovative battery design.

Thank you

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