



UNIVERSIDAD TECNICA FEDERICO SANTA MARIA

Tesis de Magister

Design and Sizing of an Energy Storage System for a Hybrid Tugboat

Tesis para optar al título de
Magister en Ciencias de la Ingeniería Electrónico

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This is the dedicatory page.

Agradecimientos

This is the abstract

Resumen

This is the abstract

Abstract

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Índice general

Agradecimientos	ii
Resumen	iii
Abstract	iv
1. Simulation results	1
1.1. Battery Cell	1
1.2. Battery Bank	2
1.3. Electric Motor	2
1.4. Diesel Propulsion Engine	4
1.5. Propeller	4
Bibliografía	5

Índice de figuras

1.1. PowerTrain	1
1.2. BattCell in power train.	1
1.3. Cell model zero order Shepherd.	2
1.4. BattCell Sim.	3
1.5. BattBank in power train.	3
1.6. ElectricMotor in power train.	4
1.7. Diesel Propulsion Engine in power train.	4
1.8. Propeller in power train.	4

Índice de tablas

1.1. Valores de los parámetros del modelo Sheperd clásico y ajustado para una celda de batería.	3
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Capítulo 1

Simulation results

The last step here, is to simulate the power train, related with all the elements inside, as battery bank, power converters, electric motor, etc.

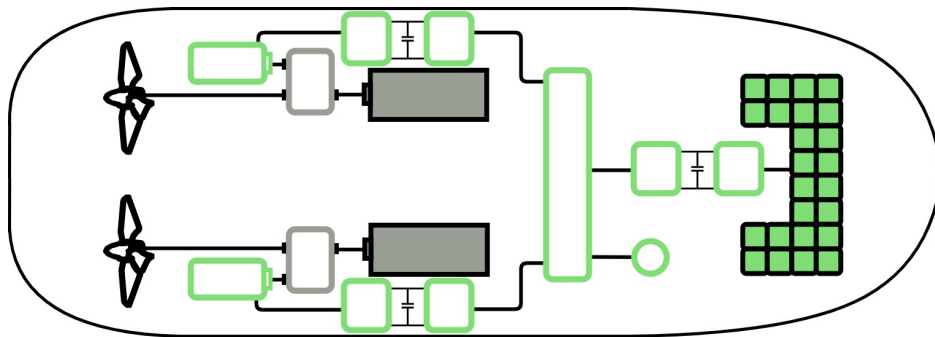


Figura 1.1: PowerTrain

1.1. Battery Cell

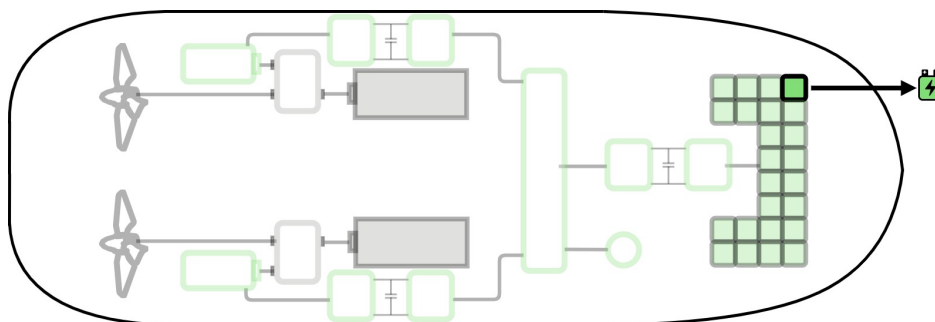


Figura 1.2: BattCell in power train.

The battery bank's design parameters are used to select a cell for electrical modeling with a Shepherd model of order 0. Technical details of the chosen cell, U27-36XP from Valence, are used to find model parameters that closely match its real discharge curve. The model shows good

similarity to the actual performance, as illustrated in Fig. 12. This enables the extrapolation of results to model a battery bank and predict its behavior across various operating profiles.

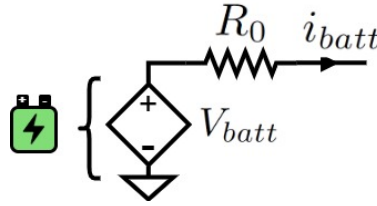


Figura 1.3: Cell model zero order Shepherd.

$$V_{batt} = V_0 - K \frac{Q_0}{Q_0 - Q} Q + A \cdot e^{-BQ} \quad (1.1)$$

$$Q = \int_0^t i_{batt}(t) dt \quad (1.2)$$

- V_{batt} : no load voltage [V].
- V_0 : Battery constant voltage [V].
- K : Polarizing voltage/resistance factor [V].
- Q : Actual battery capacity [Ah].
- Q_0 : Battery capacity [Ah].
- A : Exponential zone voltage amplitude [V].
- B : Exponential zone time constant inverse [Ah]⁻¹

[Agregar imagen de ajuste de curva](#)

$$\begin{aligned} A &= V_{full} - V_{exp} \\ B &= \frac{3}{Q_{exp}} \\ K &= \frac{(V_{full} - V_{nom} + A(e^{-B \cdot Q_{nom}} - 1))\Delta Q}{Q_{full}} \\ E_0 &= V_{full} + K + R \cdot I_{nom} - A \\ \Delta Q &= Q_{full} - Q_{nom} \end{aligned} \quad (1.3)$$

1.2. Battery Bank

1.3. Electric Motor

Tabla 1.1: Valores de los parámetros del modelo Sheperd clásico y ajustado para una celda de batería.

Parámetro	Valor parámetro Sheperd clásico	Valor parámetro Sheperd ajustado
A	[V]	[V]
B	[Ah ⁻¹]	[Ah ⁻¹]
K	[V]	[V]
E ₀	[V]	[V]

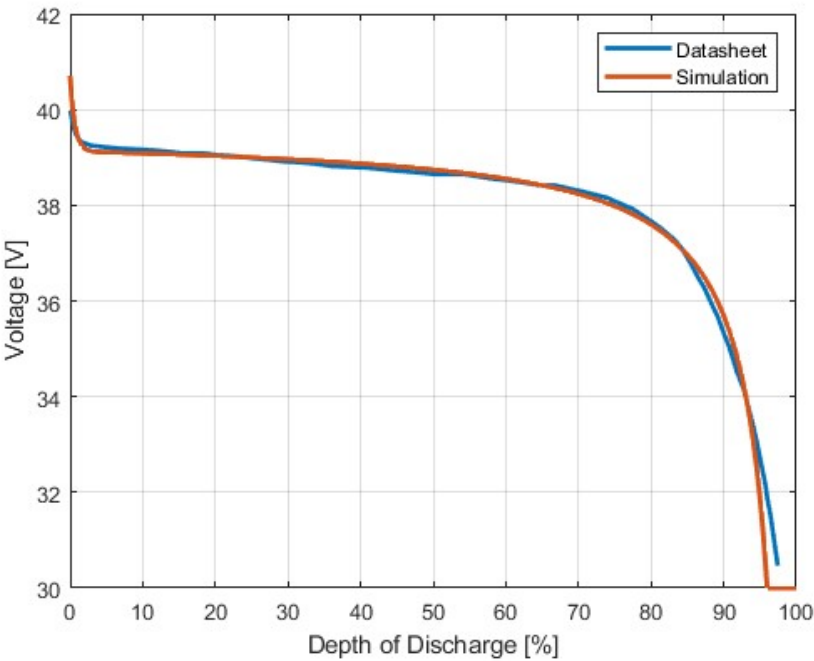


Figura 1.4: BattCell Sim.

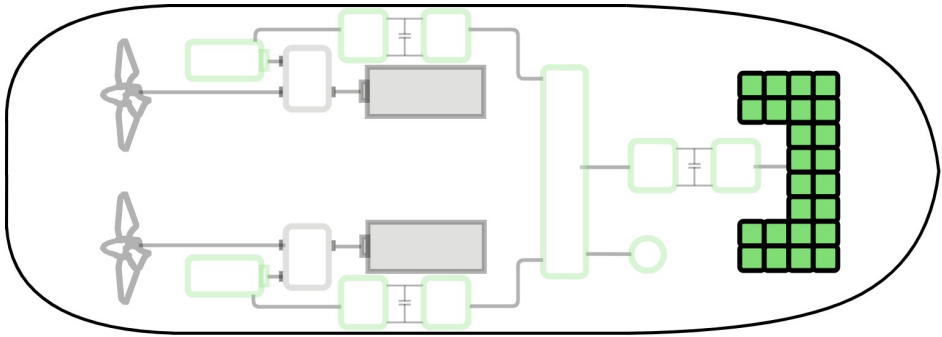


Figura 1.5: BattBank in power train.

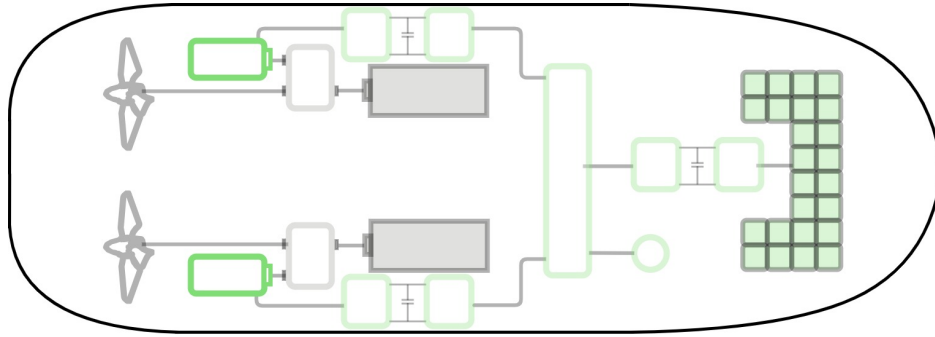


Figura 1.6: ElectricMotor in power train.

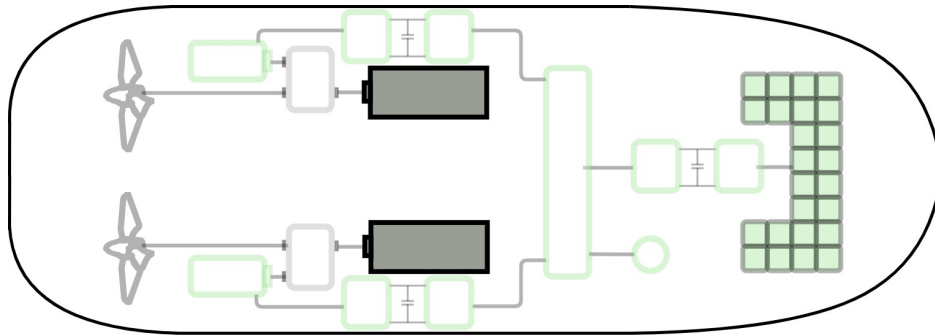


Figura 1.7: Diesel Propulsion Engine in power train.

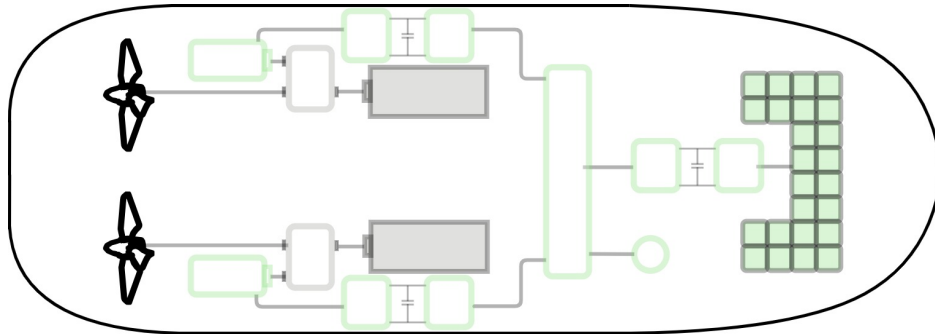


Figura 1.8: Propeller in power train.

1.4. Diesel Propulsion Engine

1.5. Propeller

- Explicación - Curva hélice - Simulaciones de Potencia

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