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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Agradecimientos

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Resumen

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Abstract

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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.

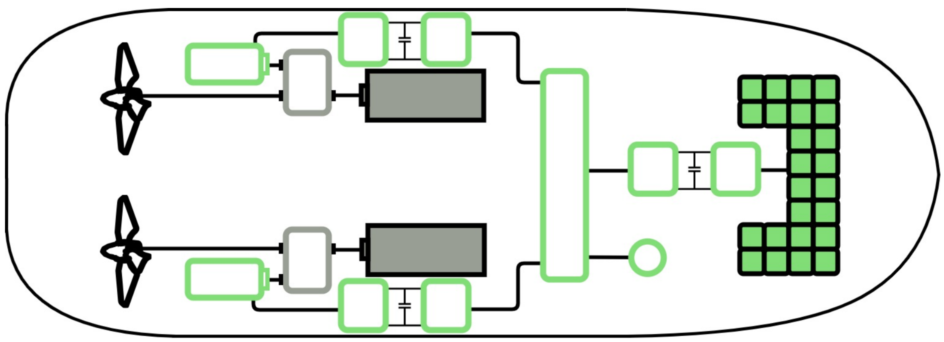


Figura 1.1: PowerTrain

1.1. Battery Cell

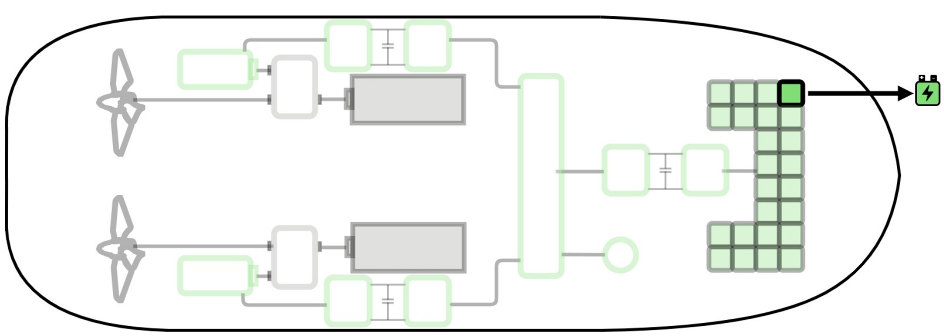


Figura 1.2: BattCell in power train.

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.

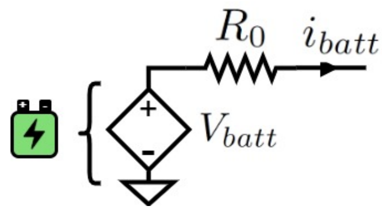


Figura 1.3: Cell model zero order Shepherd.

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

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

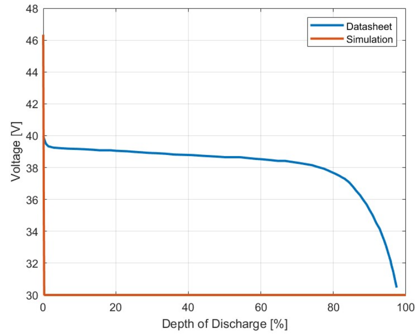
- V_{batt}: no load voltage [V].
- V_0: Battery constant voltage [V].
- K: Polarizing voltage/resistance factor [V].
- Q: Actual battery capacity [Ah].
- Q_0: Battery capacity [Ah].
- A: Exponential zone voltage amplitude [V].
- B: Exponential zone time constant inverse $[Ah]^{-1}$

Agregar imagen de ajuste de curva

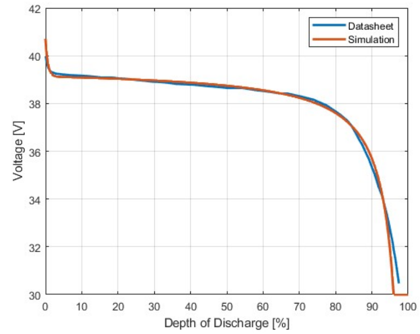
$$\begin{aligned} A &= V_{full} - V_{exp} \\ B &= \frac{3}{Q_{exp}} \\ K &= \frac{(V_{full} - V_{nom} + A(e^{-B \cdot Q_{nom}} - 1))\Delta Q}{Q_{full}} \\ V_0 &= V_{full} + K + R \cdot I_{nom} - A \\ \Delta Q &= Q_{full} - Q_{nom} \end{aligned} \tag{1.3}$$

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

Parámetro	Shepherd clásico	Sheperd ajustado
A	2.4 [V]	1.44 [V]
B	3 $[Ah^{-1}]$	3 $[Ah^{-1}]$
K	1.2857 [V]	0.0051 [V]
V_0	43.9357 [V]	39.2536 [V]



(a) Classic Shepherd



(b) Adjusted Shepherd

Figura 1.4: Implementation Model of zero order Shepherd.

1.2. Battery Bank

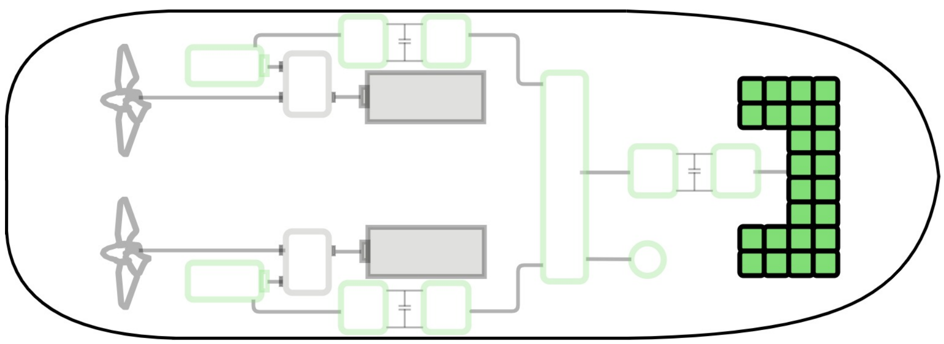


Figura 1.5: BattBank in power train.

Tabla 1.2: Valores de los parámetros del modelo Batt Bank

Parámetro	Shepherd values
N_s	19 [-]
N_p	85 [-]
A	27.36 [V]
B	0.0353 [Ah^{-1}]
K	0.0011 [V]
V_0	745.7320 [V]

1.3. Electric Motor

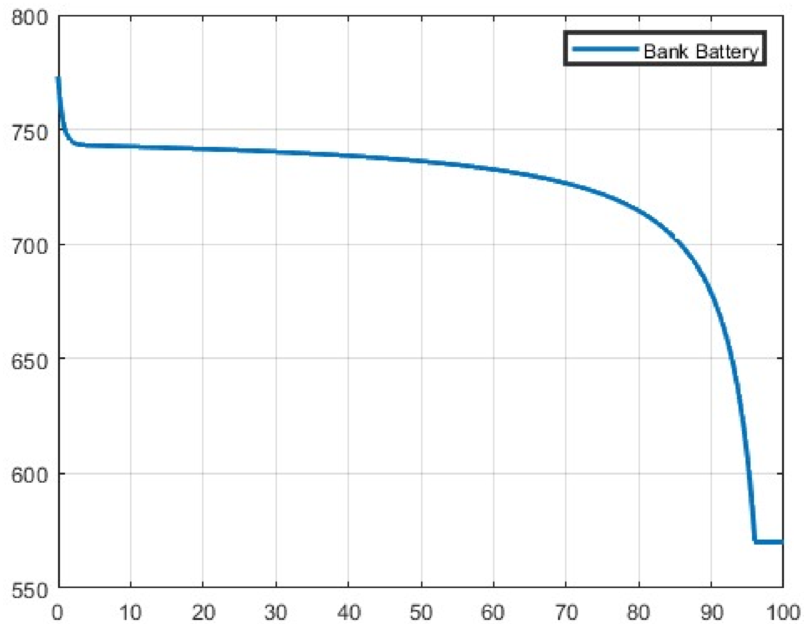


Figura 1.6: BattBank voltage profile.

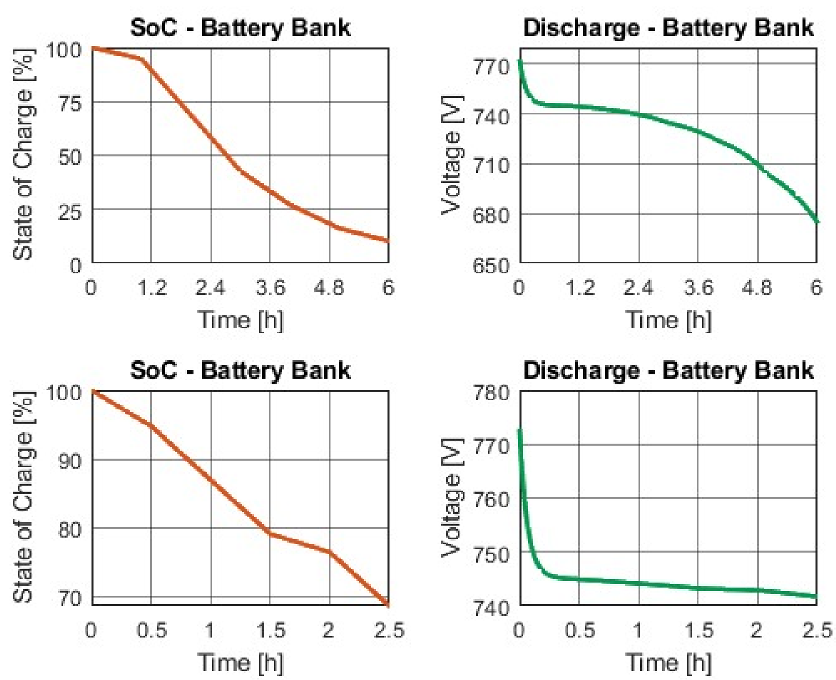


Figura 1.7: BattBank Electrical behavior.

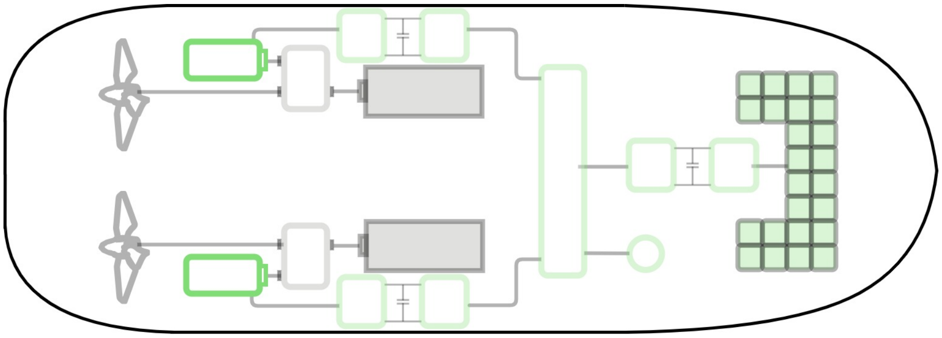


Figura 1.8: ElectricMotor in power train.

1.4. Power Inverter

1.5. Diesel Propulsion Engine

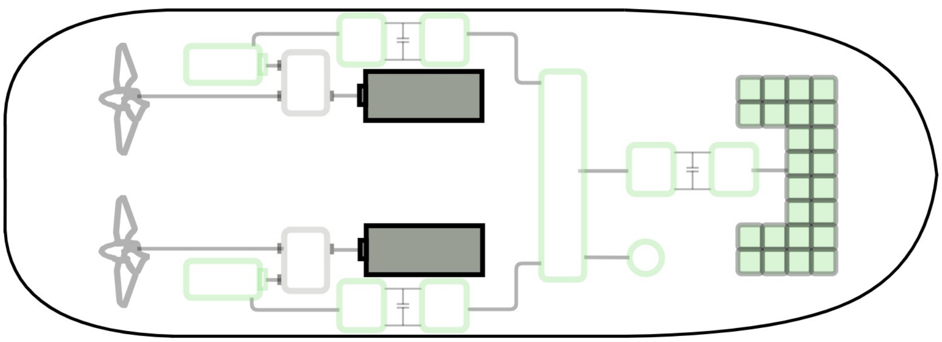


Figura 1.9: Diesel Propulsion Engine in power train.

1.6. Propeller

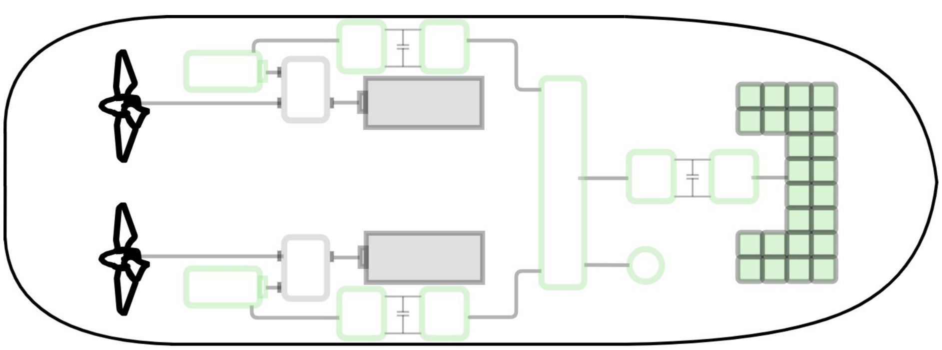


Figura 1.10: Propeller in power train.

- Explicación - Curva hélice - Simulaciones de Potencia

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