



UNIVERSIDAD TECNICA FEDERICO SANTA MARIA

Trabajo de Tesis

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

Alumno
Leonardo Solis Zamora

Profesor Guía
Dr. Marcelo Pérez Leiva

Comisión evaluadora
Nombre del primer correferente, Correferente, UTFSM
Nombre del segundo correferente, Correferente, CODELCO

Enero 2025 , Valparaíso, Chile

This is the dedicatory page.

Agradecimientos

This is the abstract

Resumen

This is the abstract

Abstract

This is the abstract

Índice general

Agradecimientos	ii
Resumen	iii
Abstract	iv
1. Introducción	1
1.1. Motivation and Background	1
1.2. Challenges and Research Opportunities	1
1.3. Thesis Objectives and Outline	1
Bibliografía	2

Índice de figuras

Índice de tablas

Capítulo 1

Introducción

1.1. Motivation and Background

The growing global concern over climate change has significantly pressured industries to adopt sustainable practices. The maritime sector, responsible for approximately 30 % of global CO₂ emmissions, has continuously increased int emissions, as shown in Fig. 1.

1.2. Challenges and Research Opportunities

1.3. Thesis Objectives and Outline

[1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23],

Bibliografía

- [1] A. Carreno, M. Malinowski, M. A. Perez, and J. Ding, "Effects of grid voltage and load unbalances on the efficiency of a hybrid distribution transformer," *IEEE Open Journal of the Industrial Electronics Society*, vol. 5, pp. 1206–1220, 2024.
- [2] J. Yin, N. Dai, S. Vazquez, M. A. Perez, B. Zhang, J. I. Leon, and L. G. Franquelo, "Direct pulsewidth modulation technique for modular multilevel converters based on full-bridge submodules," *IEEE Transactions on Power Electronics*, pp. 1–14, 2024.
- [3] J. Yin, N. Dai, J. I. Leon, M. A. Perez, S. Vazquez, and L. G. Franquelo, "Common-mode-voltage regulation of modular multilevel converters through model predictive control," *IEEE Transactions on Power Electronics*, vol. 39, no. 6, pp. 7167–7180, 2024.
- [4] A. Carreno, M. Malinowski, M. A. Perez, and C. R. Baier, "Circulating active power flow analysis in a hybrid transformer with the series converter connected to the primary side," *IEEE Transactions on Industrial Electronics*, vol. 71, no. 10, pp. 11 775–11 784, 2024.
- [5] J. Yin, N. Dai, S. Vazquez, A. Marquez, J. I. Leon, M. A. Perez, and L. G. Franquelo, "An improved indirect pulsewidth modulation technique for modular multilevel converters," *IEEE Transactions on Power Electronics*, vol. 39, no. 1, pp. 733–743, 2024.
- [6] A. Carreno, M. A. Perez, and M. Malinowski, "State-feedback control of a hybrid distribution transformer for power quality improvement of a distribution grid," *IEEE Transactions on Industrial Electronics*, vol. 71, no. 2, pp. 1147–1157, 2024.
- [7] D. S. D'antonio, O. López-Santos, A. Navas-Fonseca, F. Flores-Bahamonde, and M. A. Pérez, "Multi-mode master-slave control approach for more modular and reconfigurable hybrid microgrids," *IEEE Access*, vol. 11, pp. 55 334–55 348, 2023.
- [8] C. R. Baier, F. A. Villarroel, M. A. Torres, M. A. Pérez, J. C. Hernández, and E. E. Espinosa, "A predictive control scheme for a single-phase grid-supporting quasi-z-source inverter and its integration with a frequency support strategy," *IEEE Access*, vol. 11, pp. 5337–5351, 2023.
- [9] J. Samanes, L. Rosado, E. Gubia, J. Lopez, and M. A. Perez, "Deadbeat voltage control for a grid-forming power converter with lcl filter," *IEEE Transactions on Industry Applications*, vol. 59, no. 2, pp. 2473–2482, 2023.
- [10] M. Liserre, M. A. Perez, M. Langwasser, C. A. Rojas, and Z. Zhou, "Unlocking the hidden capacity of the electrical grid through smart transformer and smart transmission," *Proceedings of the IEEE*, vol. 111, no. 4, pp. 421–437, 2023.

- [11] F. A. Villarroel, J. R. Espinoza, M. A. Pérez, C. R. Baier, J. A. Rohten, R. O. Ramírez, E. S. Pulido, and J. J. Silva, "A predictive shortest-horizon voltage control algorithm for non-minimum phase three-phase rectifiers," *IEEE Access*, vol. 10, pp. 107 598–107 615, 2022.
- [12] M. A. Perez, S. Ceballos, G. Konstantinou, J. Pou, and R. P. Aguilera, "Modular multilevel converters: Recent achievements and challenges," *IEEE Open Journal of the Industrial Electronics Society*, vol. 2, pp. 224–239, 2021.
- [13] F. A. Villarroel, J. R. Espinoza, M. A. Pérez, R. O. Ramírez, C. R. Baier, D. Sbárbaro, J. J. Silva, and M. A. Reyes, "Stable shortest horizon fcs-mpc output voltage control in non-minimum phase boost-type converters based on input-state linearization," *IEEE Transactions on Energy Conversion*, vol. 36, no. 2, pp. 1378–1391, 2021.
- [14] J. Yin, J. I. Leon, M. A. Perez, L. G. Franquelo, A. Marquez, and S. Vazquez, "Model predictive control of modular multilevel converters using quadratic programming," *IEEE Transactions on Power Electronics*, vol. 36, no. 6, pp. 7012–7025, 2021.
- [15] J. Yin, J. I. Leon, M. A. Perez, L. G. Franquelo, A. Marquez, B. Li, and S. Vazquez, "Variable rounding level control method for modular multilevel converters," *IEEE Transactions on Power Electronics*, vol. 36, no. 4, pp. 4791–4801, 2021.
- [16] C. A. Reusser, H. A. Young, J. R. Perez Osses, M. A. Perez, and O. J. Simmonds, "Power electronics and drives: Applications to modern ship propulsion systems," *IEEE Industrial Electronics Magazine*, vol. 14, no. 4, pp. 106–122, 2020.
- [17] F. Ruiz, M. A. Perez, J. R. Espinosa, T. Gajowik, S. Stynski, and M. Malinowski, "Surveying solid-state transformer structures and controls: Providing highly efficient and controllable power flow in distribution grids," *IEEE Industrial Electronics Magazine*, vol. 14, no. 1, pp. 56–70, 2020.
- [18] Q. Yang, M. Saeedifard, and M. A. Perez, "Sliding mode control of the modular multilevel converter," *IEEE Transactions on Industrial Electronics*, vol. 66, no. 2, pp. 887–897, 2019.
- [19] C. A. Rojas, S. Kouro, M. A. Perez, and J. Echeverria, "Dc–dc mmc for hvdc grid interface of utility-scale photovoltaic conversion systems," *IEEE Transactions on Industrial Electronics*, vol. 65, no. 1, pp. 352–362, 2018.
- [20] A. Dekka, B. Wu, R. L. Fuentes, M. Perez, and N. R. Zargari, "Evolution of topologies, modeling, control schemes, and applications of modular multilevel converters," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 5, no. 4, pp. 1631–1656, 2017.
- [21] O. Menendez, F. A. Auat Cheein, M. Perez, and S. Kouro, "Robotics in power systems: Enabling a more reliable and safe grid," *IEEE Industrial Electronics Magazine*, vol. 11, no. 2, pp. 22–34, 2017.
- [22] A. Dekka, B. Wu, R. L. Fuentes, M. Perez, and N. R. Zargari, "Voltage-balancing approach with improved harmonic performance for modular multilevel converters," *IEEE Transactions on Power Electronics*, vol. 32, no. 8, pp. 5878–5884, 2017.
- [23] C. D. Fuentes, C. A. Rojas, H. Renaudineau, S. Kouro, M. A. Perez, and T. Meynard, "Experimental validation of a single dc bus cascaded h-bridge multilevel inverter for multistring photovoltaic systems," *IEEE Transactions on Industrial Electronics*, vol. 64, no. 2, pp. 930–934, 2017.