UNIVERSIDAD TECNICA
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Agradecimientos

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Introducción

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

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Apéndice A

Sample Code for Appendix

This appendix provides an example of code used in the project. The code is displayed using the `verbatim` environment to preserve formatting and indentation.

A.1. Example Code: Bandgap Calculation in Python

```
# Python code to calculate the bandgap of a semiconductor
def calculate_bandgap(Ec, Ev):
    """
    Function to calculate the bandgap energy.
    Ec: Conduction band energy (in eV)
    Ev: Valence band energy (in eV)
    Returns: Bandgap energy (in eV)
    """
    bandgap = Ec - Ev
    return bandgap

# Example usage
Ec = 3.4  # Conduction band energy for GaN (eV)
Ev = 0.0  # Valence band energy (reference, eV)

bandgap = calculate_bandgap(Ec, Ev)
print(f"The bandgap energy is {bandgap} eV.")
```

Apéndice B

Supplementary Tables

This appendix contains supplementary tables that provide additional data and detailed information used in this study.

B.1. Material Properties of GaN and Related Semiconductors

Tabla B.1: Material Properties of GaN and Related Semiconductors.

Property	**GaN**	**SiC**	**Si**
Bandgap Energy (eV)	3.4	3.3	1.1
Thermal Conductivity (W/m·K)	130	490	150
Breakdown Electric Field (MV/cm)	3.3	2.8	0.3
Electron Mobility ($cm^2/V \cdot s$)	1200	900	1400
Lattice Constant (Å)	3.189	4.358	5.431

B.2. Experimental Parameters for Epitaxial Growth

Tabla B.2: Experimental Parameters for MOCVD Growth of GaN.

Parameter	**Value**	**Unit**
Growth Temperature	1050	°C
Reactor Pressure	200	mbar
Precursor Flow Rate (TMA/Ga)	50	sccm
NH_3 Flow Rate	5000	sccm
Growth Rate	2.5	μm/hr
Buffer Layer Thickness	25	nm

Tabla B.3: Performance Metrics of Fabricated GaN HEMTs.

Metric	**Measured Value**	**Unit**	**Device ID**
Threshold Voltage (V_{th})	-2.5	V	D1
Maximum Current Density	800	mA/mm	D1
Peak Transconductance (g_m)	200	mS/mm	D1
Breakdown Voltage	1200	V	D1

B.3. Device Performance Metrics

B.4. Comparison of Simulation and Experimental Results

Tabla B.4: Comparison of Simulation and Experimental Results.

Parameter	**Simulation**	**Experiment**
Electron Mobility ($cm^2/V\cdot s$)	1350	1200
2DEG Density (cm^{-2})	$1{,}5 \times 10^{13}$	$1{,}2 \times 10^{13}$
Threshold Voltage (V_{th})	-2.2	-2.5
Breakdown Voltage (V)	1300	1200

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.