RESEARCH IN POWER ELECTRONICS AND CONTROL

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Power & Energy Society - FIUNA

San Lorenzo – Paraguay
June 20th, 2017

Content Index

1. Motivation
   - Laboratory of Power and Control Systems
   - Concluded Projects

2. Control of Multiphase Drives

3. Matrix Converters

4. Active Power Filters

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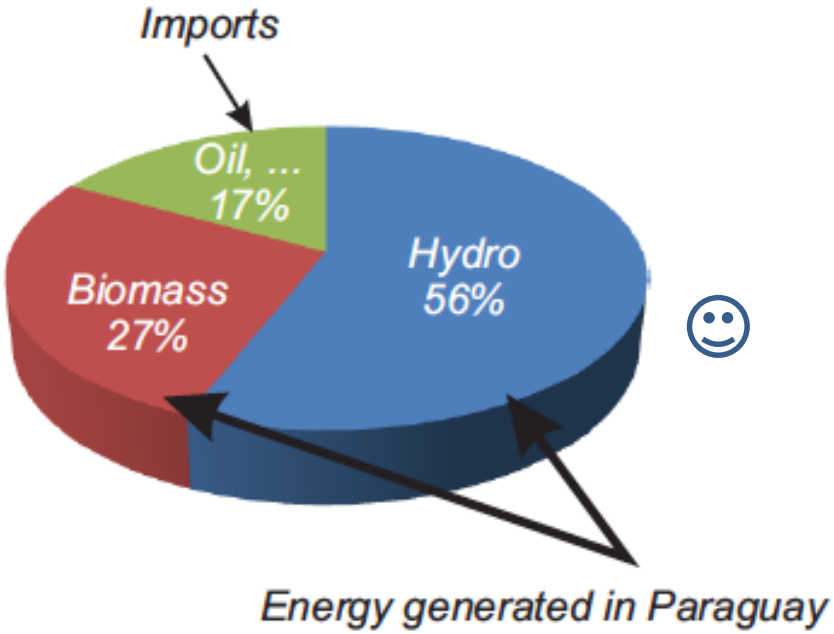
MOTIVATION

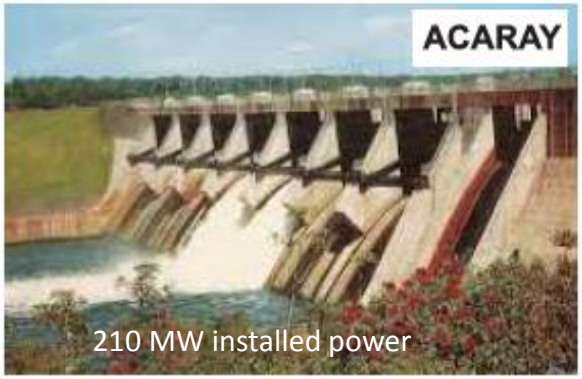
Energy matrix structure in Paraguay



Source: Vice Ministry of mines and energy
"National energy balance 2012"

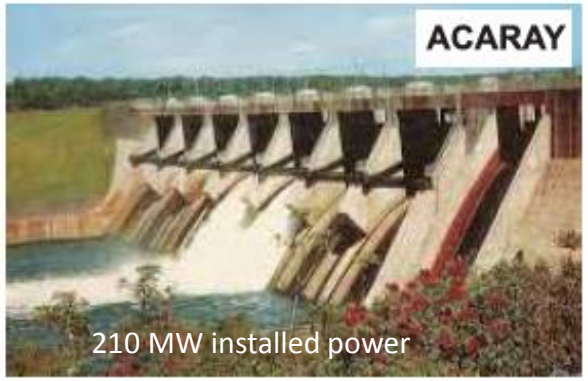
- Wind farms ✗
- Solar plants ✗
- Distributed generation ✗

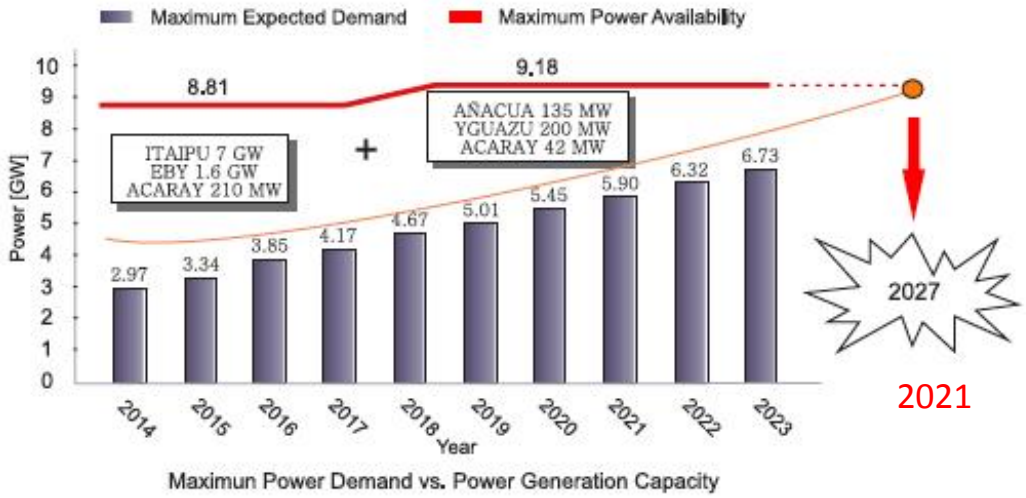
MOTIVATION



- The main electric energy resource of Py is hydroelectric power plants.
- The average annual growth in electricity use is quantified around 8%.

MOTIVATION





- Probably in 2027 power demand could exceed the power generation capacity.
- Causing a serious problem of availability of electric energy.

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LABORATORY OF POWER AND CONTROL SYSTEMS

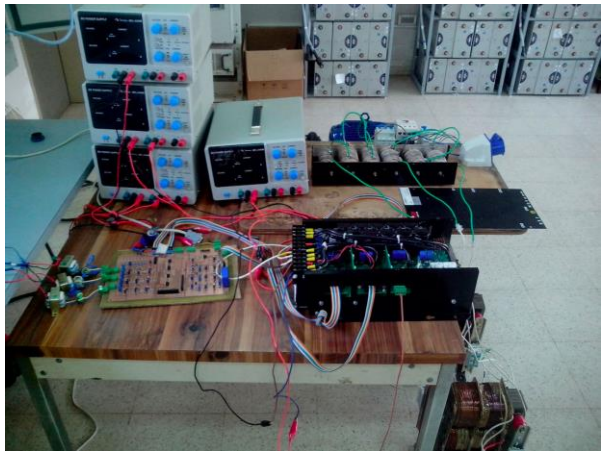
- ✓ LSPyC
  www.dspyc.com.py
- ✓ Created in 2009.
- ✓ Staff
  - 6 full time professors.
  - 2 PhD students.
  - 10 MSc students.
  - 10 junior researchers.
  - 1 administrative.

- ✓ Funds
  - 1 PhD program (1st Ed. 2017): 200,000 US$
  - 1 MSc program (1st Ed. 2015-2017): 200,000 US$
  - 7 Research Projects: 1,750,000 US$

- ✓ > 10 partners in 7 countries: UTalca, USevilla, ETS, …

RESEARCH THEMES

- Advanced Control of power converters for renewable energy applications and machines and drives:
  - Predictive control, parameter estimation, modelling, fault tolerant control.
  - Sensorless control.
  - Nonlinear control.
- Electric Machines and Drives and Power Converters:
  - Multiphase induction machine
  - Matrix converters Multilevel inverters.
- Renewables:
  - Solar (PV) and Eolic.
  - Grid interconnection.
  - Active power filters.



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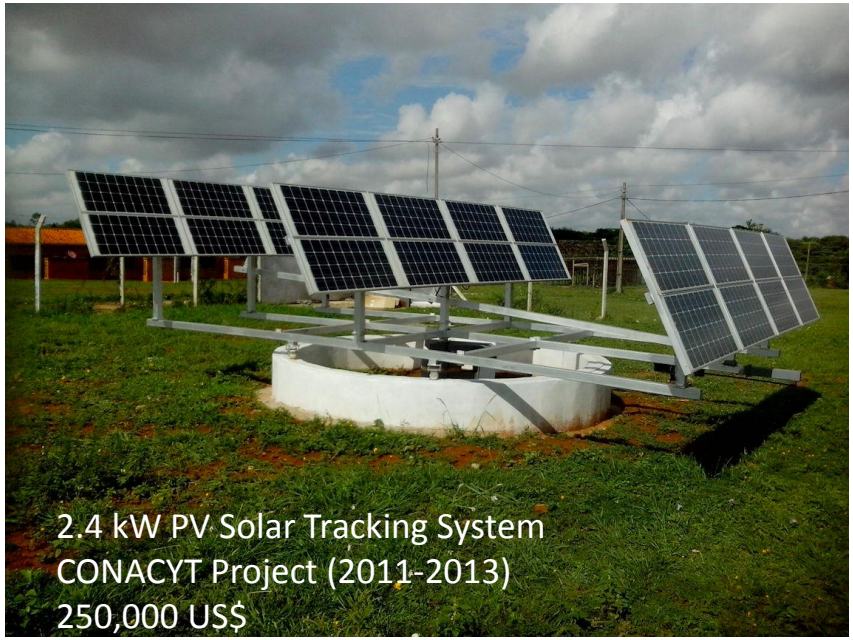
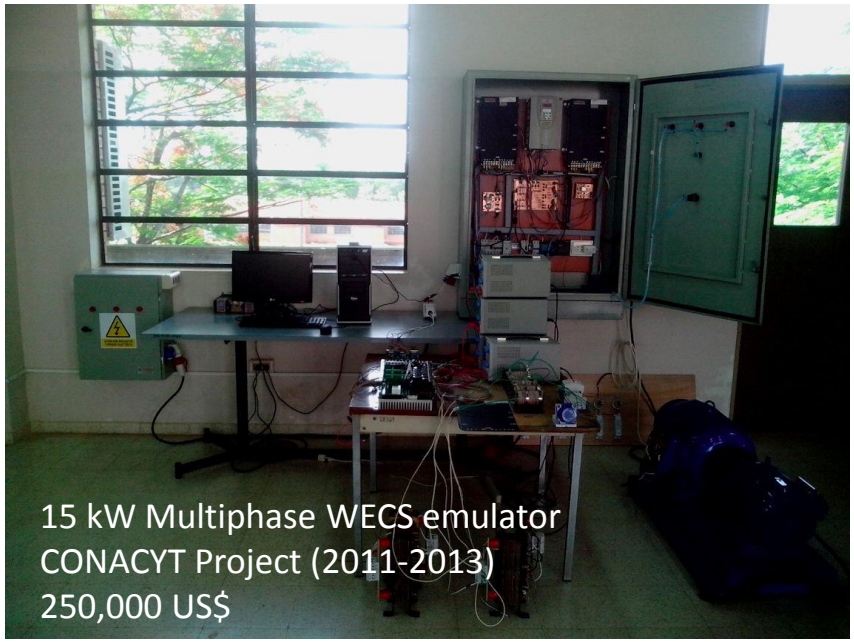
CONCLUDED PROJECTS





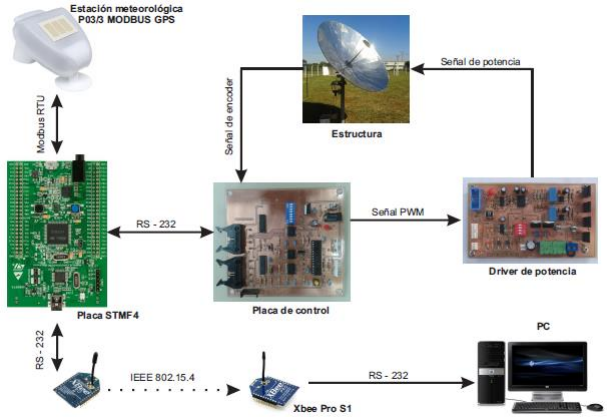
R. Gregor, Y. Takase, J. Rodas, L. Carreras, D. Gregor, A. López, **"Biaxial Solar Tracking System based on the MPPT Approach Integrating ICTs for Photovoltaic Applications,"** International Journal of Photoenergy, 2015.

J. Rodas, "**New Approaches for Distributed Generation Systems based on Solar and Wind Energy**," Quorum Comunica‹o, 2013, ISBN 978-856-31-9009-3.

Undergraduate projects

- Grid interconnection
- Bi-directional meter
- Concentrated solar colector
- Anemometer

…



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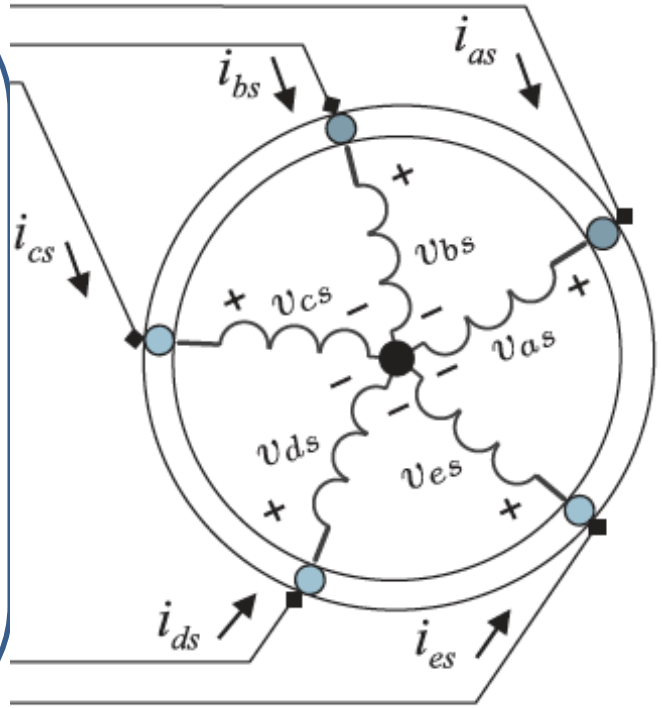
MULTIPHASE DRIVES

Fault-tolerance is one of the most interesting feature of wind energy conversion systems (WECS).
The ability to maintain operation even after an open-phase fault, allows for the system operators to maintain energy production, providing tangible economic benefits.

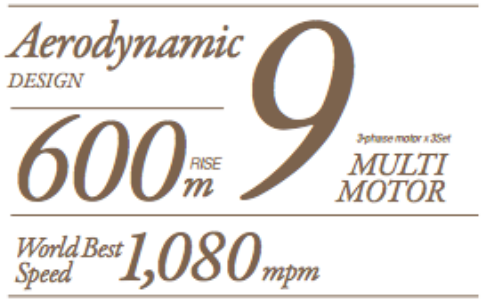


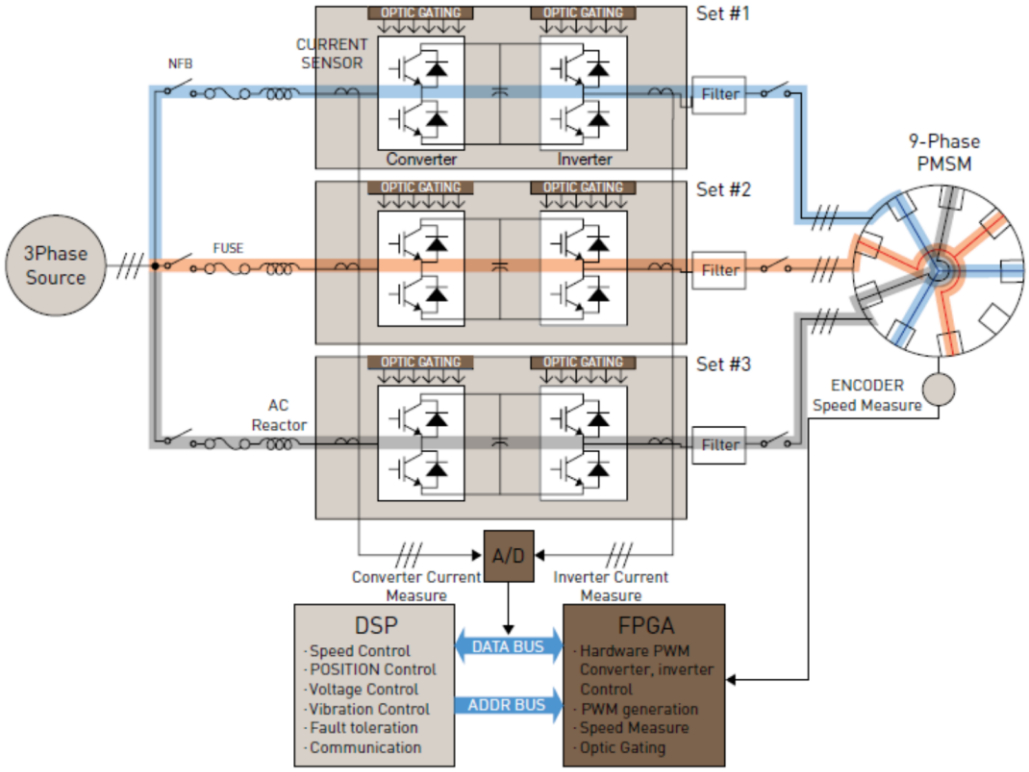
Recently, the use of multiphase drives for WECS have been proposed due to their inherent fault tolerance capability and the capacity to manage higher power ratings.

MULTIPHASE DRIVES: APPLICATIONS

Industry Applications

High Speed Elevator:
9-phase PMSM





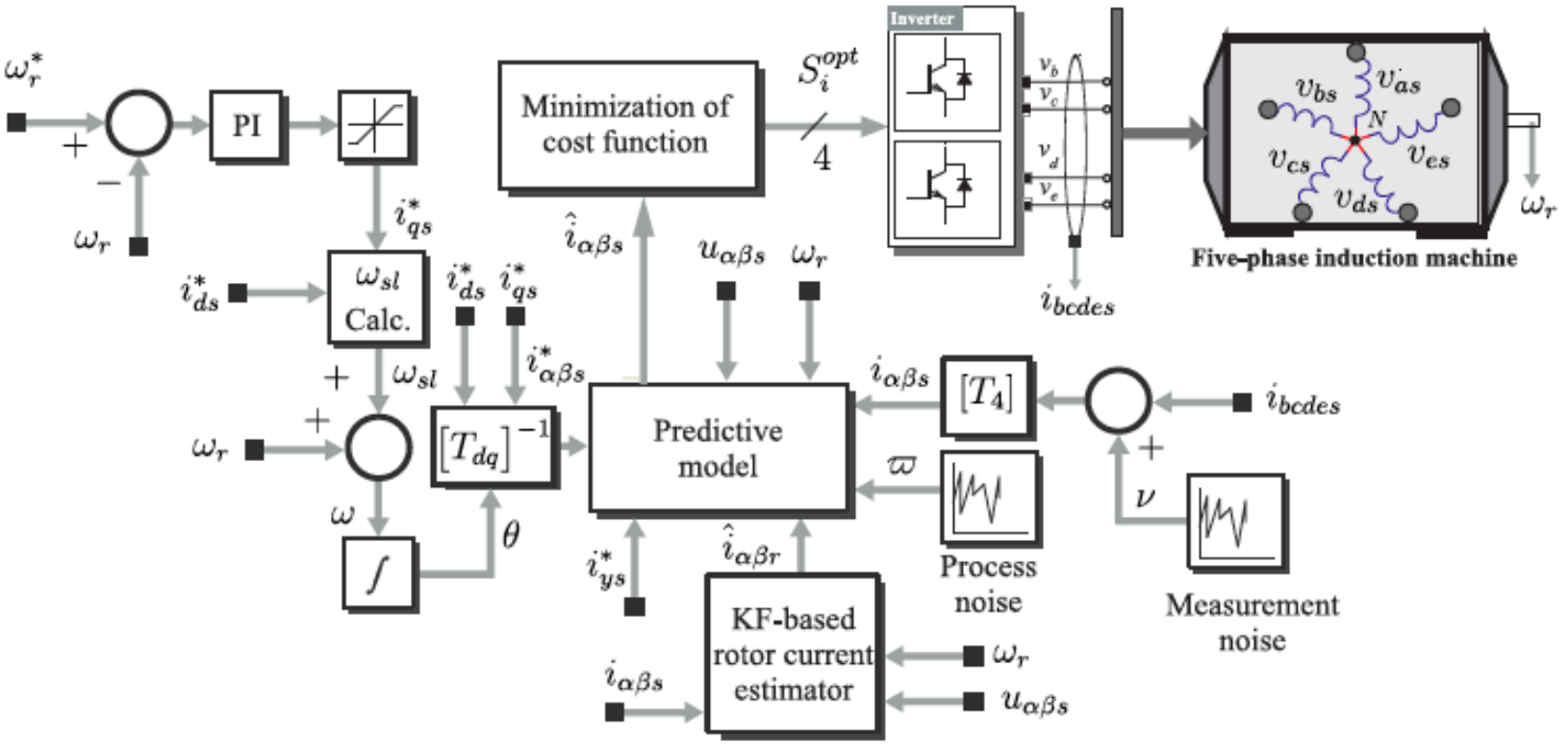
MULTIPHASE DRIVES: APPLICATIONS

Industry Applications

Submarines:

- 12-Phase PM
- 13-Phase PM

FCS-MPC IN MULTIPHASE DRIVES

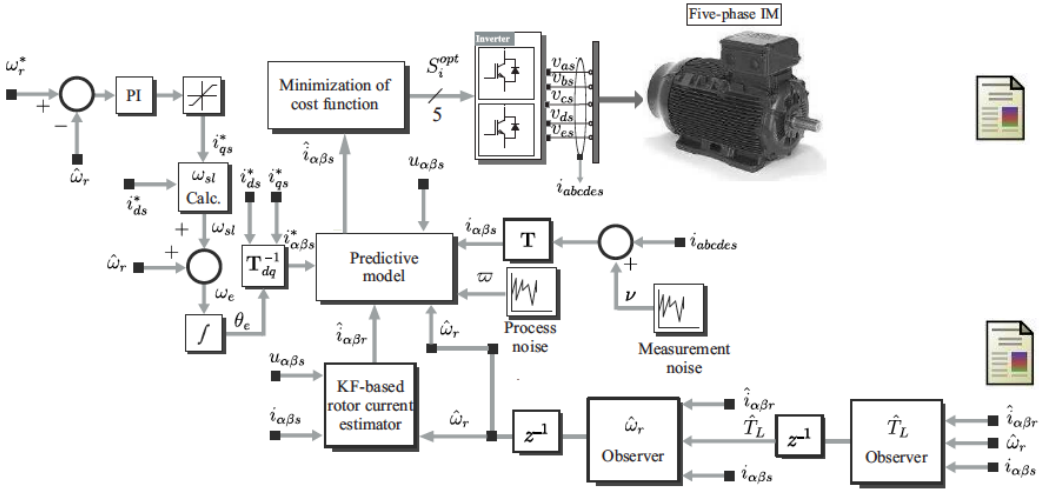


J. Rodas, F. Barrero, M. R. Arahal, C. Martín, R. Gregor, "**On-Line Estimation of Rotor Variables in Predictive Current Controllers: a Case Study using Five-Phase Induction Machines**," *IEEE Transactions on Industrial Electronics*, vol. 63, no. 9, pp. 5348–5356, Sep. 2016. (IF: 7.168)

J. Rodas, C. Martín, M. R. Arahal, F. Barrero, R. Gregor, "**Influence of Covariance-Based ALS Methods in the Performance of Predictive Controllers with Rotor Current Estimation**," *IEEE Transactions on Industrial Electronics, vol. 64, no. 4, pp. 2602–2607, Apr. 2017.* (IF: 7.168)

J. Rodas, H. Guzmán, R. Gregor, F. Barrero, "**Model Predictive Current Controller using Kalman Filter for Fault-Tolerant Five-Phase Wind Energy Conversion Systems**," *The 7th International Symposium on Power Electronics for Distributed Generation Systems: PEDG 2016, Vancouver, Canada, Jun. 27-30, 2016.*

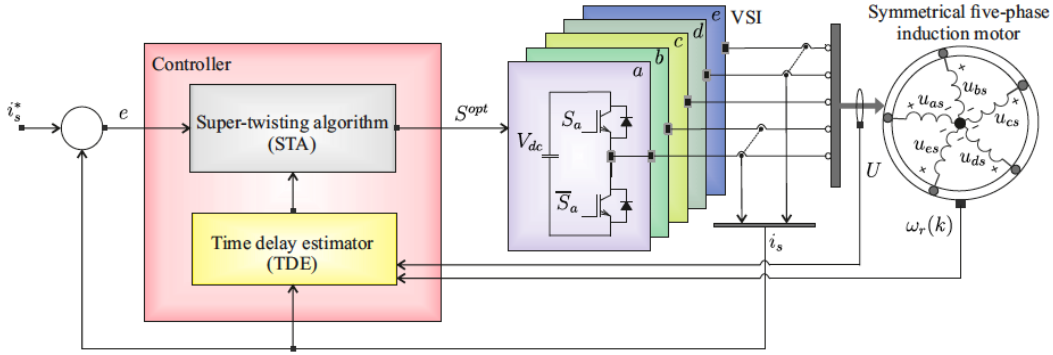
OTHER CONTRIBUTIONS



Sensorless

O. González, J. Rodas, R. Gregor, M. Ayala, M. Rivera, **"Speed Sensorless Predictive Current Control of a Five-Phase Induction Machine,"** *IEEE Conference on Industrial Electronics and Applications: ICIEA 2017*, Siem Reap, Combodia, Jun. 18-20, 2017.

M. Ayala, O. Gonzalez, J. Rodas, R. Gregor, J. Doval-Gandoy, **"A Speed-Sensorless Predictive Current Control of Multiphase Induction Machines Using a Kalman Filter for Rotor Current Estimator,"** *International Conference on Electrical Systems for Aircraft, Railway, Ship propulsion and Road Vehicles & International Transportation Electrification Conference: ESARS - ITEC*, Toulouse, France, Nov. 2-4, 2016.



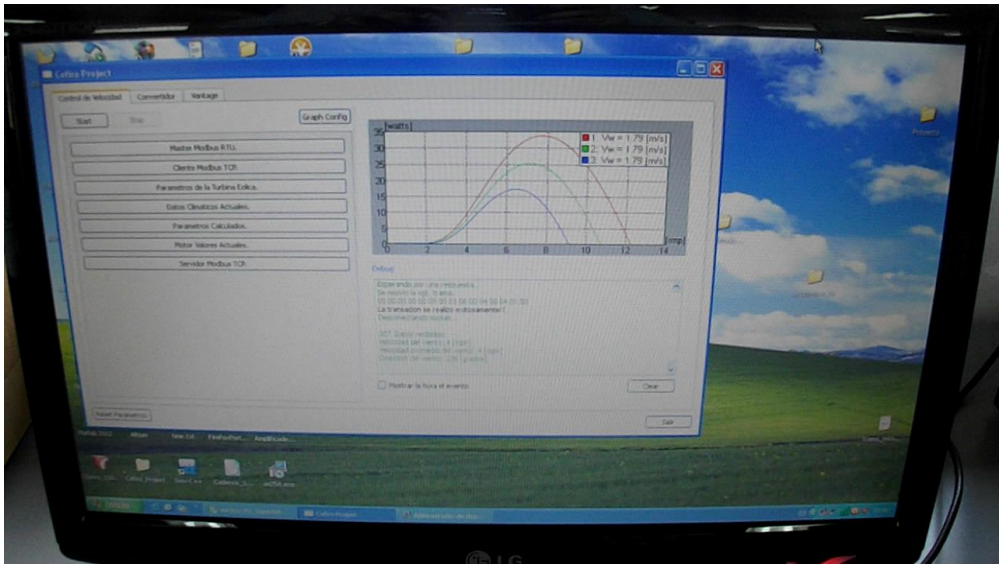
Sliding Mode Control

Y. Kali, J. Rodas, M. Saad, R. Gregor, K. Bejelloun, J. Doval-Gandoy, **"Current Control based on Super-Twisting Algorithm with Time Delay Estimation for a Five-Phase Induction Motor Drive,"** *IEEE International Electric Machines & Drives Conference: IEMDC*, Miami, FL, USA, May 21-24, 2017.

EXPERIMENTAL SETUP

Análisis y evaluación de accionamientos multifásicos orientado a la generación de energía eléctrica basada en fuentes potenciales de energías renovables en Paraguay

Desarrollo y análisis de eficiencia de nuevos algoritmos de control enfocados al generador hexafásico en aplicaciones de energía eólica



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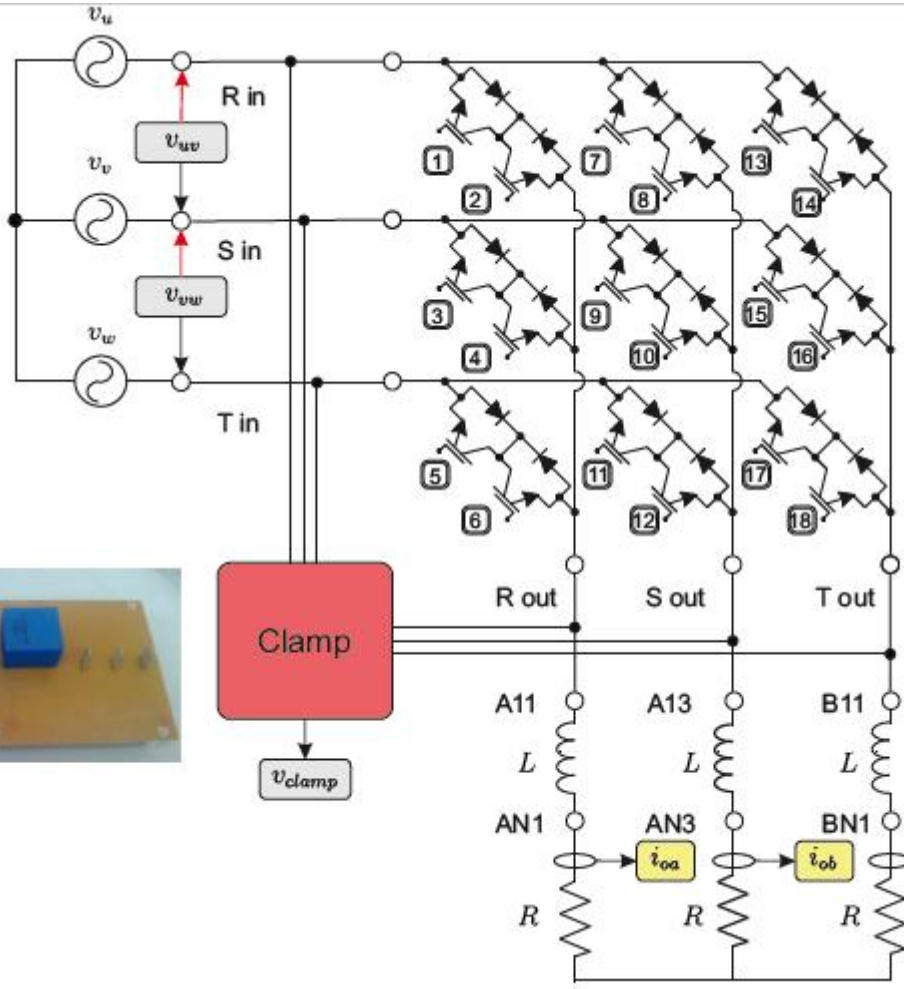
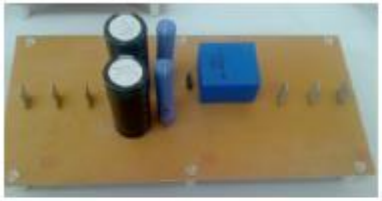
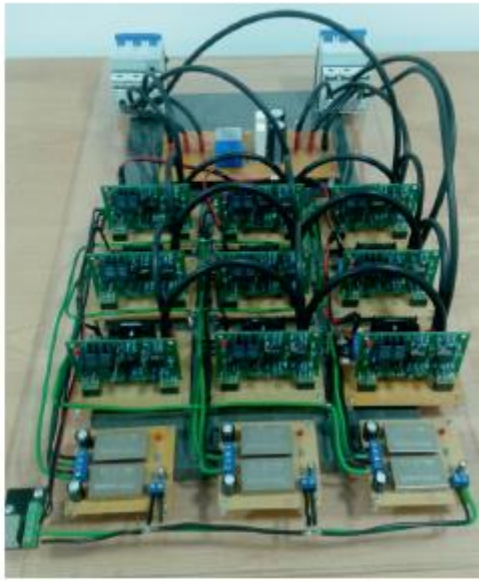
MULTI-MODULAR MATRIX CONVERTERS



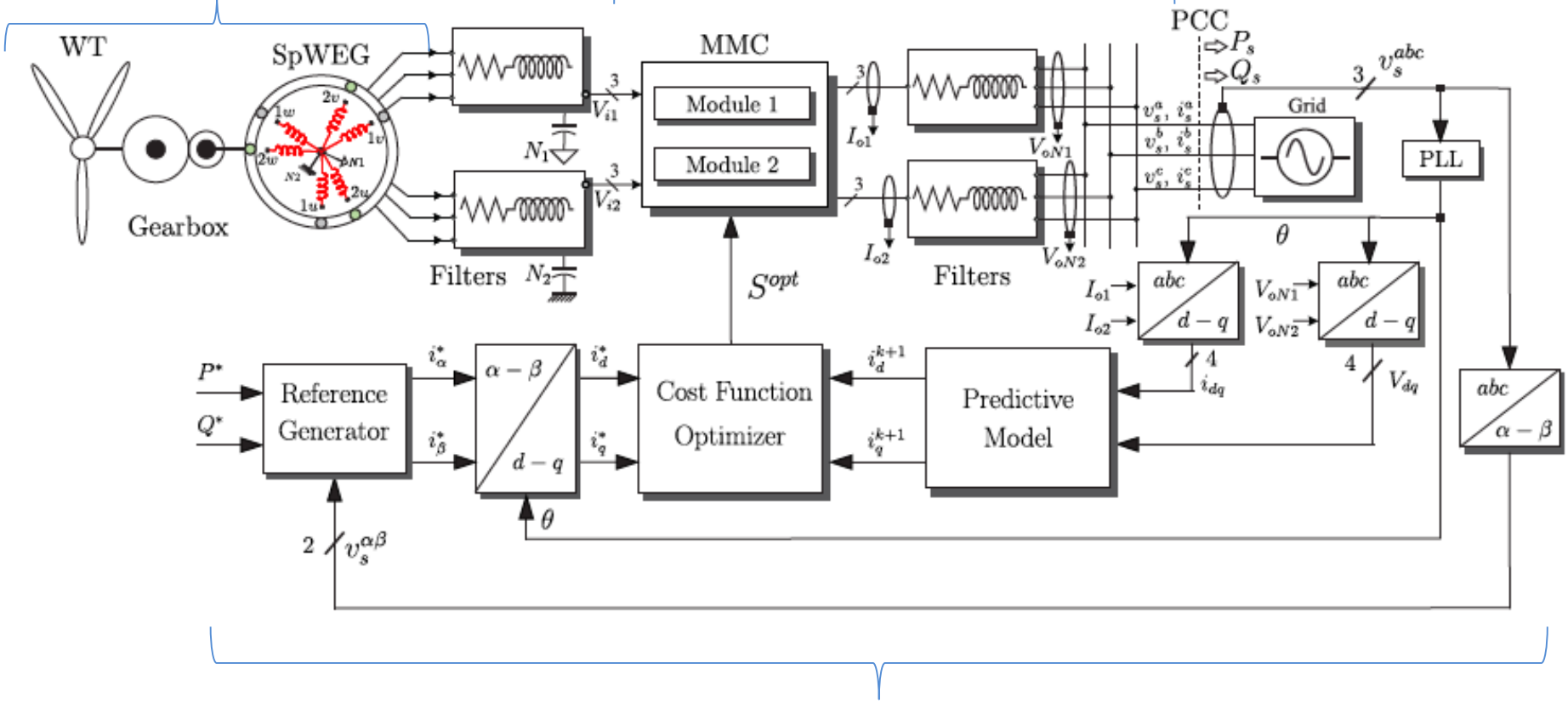




MULTI-MODULAR MATRIX CONVERTERS

Project #1: Real Multiphase-based Wind Turbine

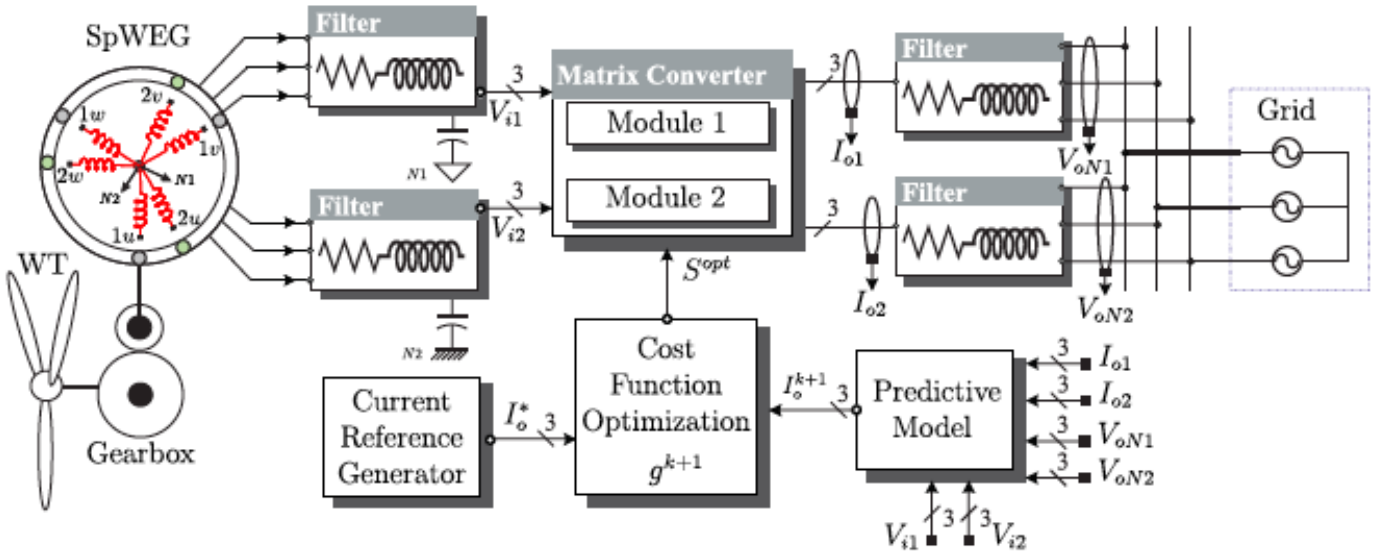
Project #2: Multi-modular matrix converter



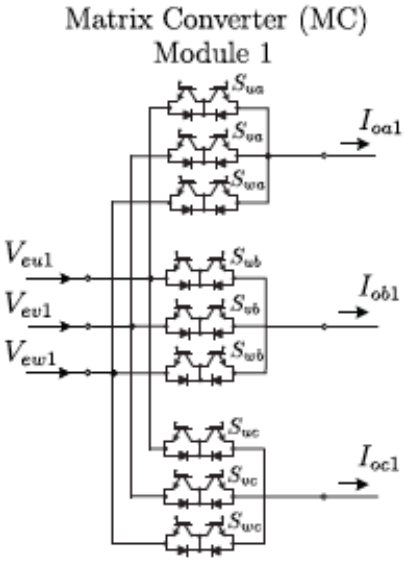
MPC applied to power converters

FCS-MPC IN MATRIX CONVERTERS

Proposed multi-modular matrix converter topology applied to the SpWEG.



Matrix converter topology.



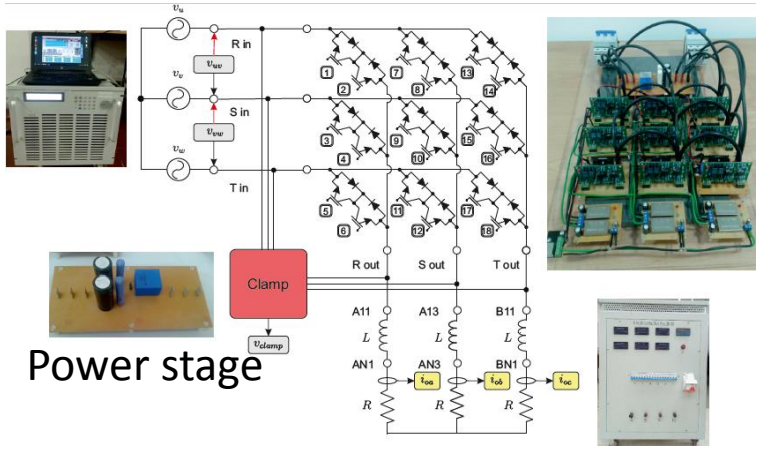
D. Caballero, F. Gavilan, E. Maqueda, R. Gregor, S. Toledo, J. Rodas, D. Gregor, "**Active and Reactive Power Control Strategy for Grid-Connected Six-Phase Generator by Using Multi-Modular Matrix Converters**," *Journal on Systemics, Cybernetics and Informatics , vol. 14, no. 6, pp. 57–61, 2016.*

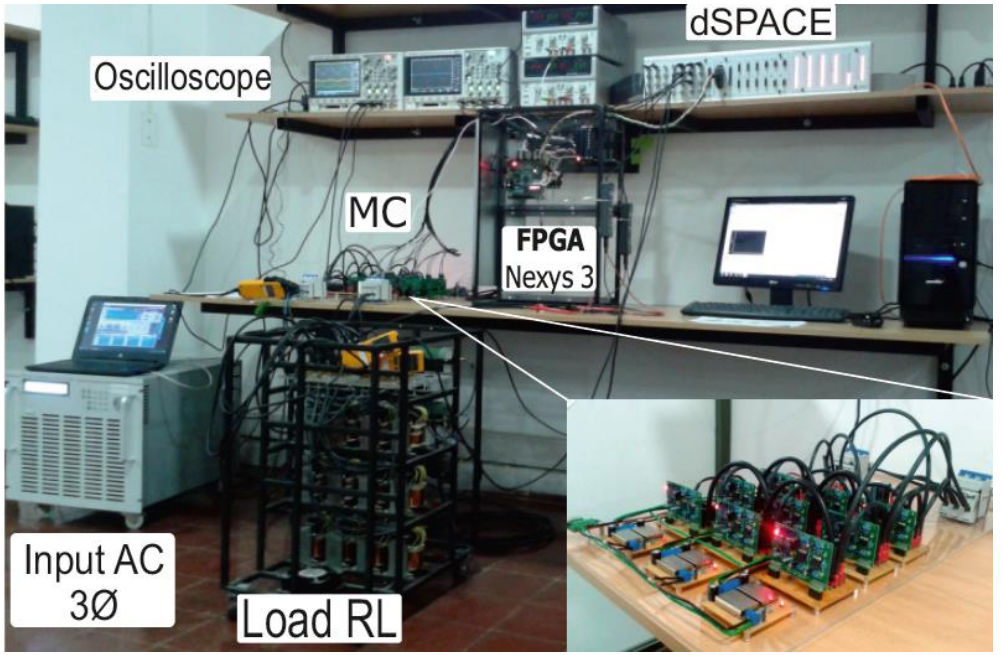
S. Toledo, R. Gregor, M. Rivera, J. Rodas, D. Gregor, D. Caballero, F. Gavilan, E. Maqueda, P. Wheler, "**Multi-Modular Matrix Converter Topology applied to Distributed Generation Systems**," *The 8th IET International Conference on Power Electronics, Machines and Drives: PEMD 2016 , Glasgow, Scotland, Apr. 19-21, 2016.*

S. Toledo, M. Rivera, R. Gregor, J. Rodas, L. Comparatore, "**Predictive Current Control with Reactive Power Minimization in Six-Phase Wind Energy Generator using Multi-Modular Direct Matrix Converter**," *Andean Council International Conference: ANDESCON, Arequipa, Peru, Oct. 19-21, 2016.*

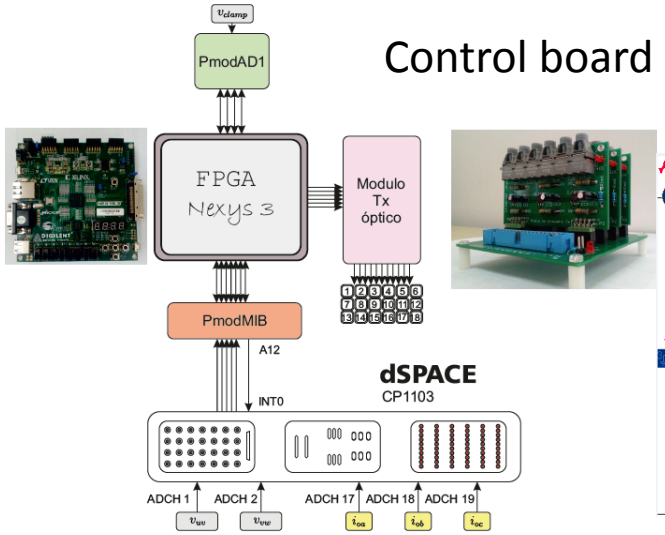
MATRIX CONVERTERS: EXPERIMENTAL SETUP

Multi-modular matrix converter

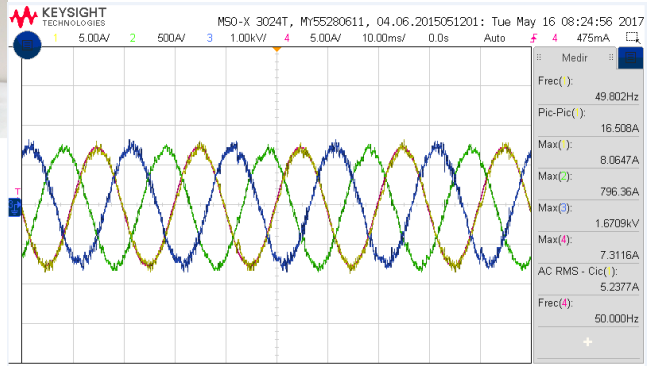


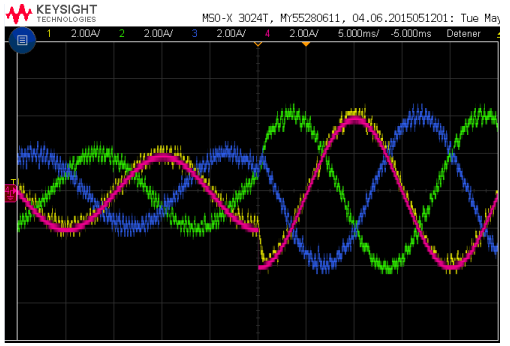


Control board



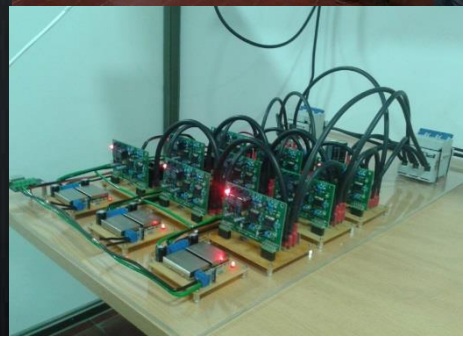
Experimental Results

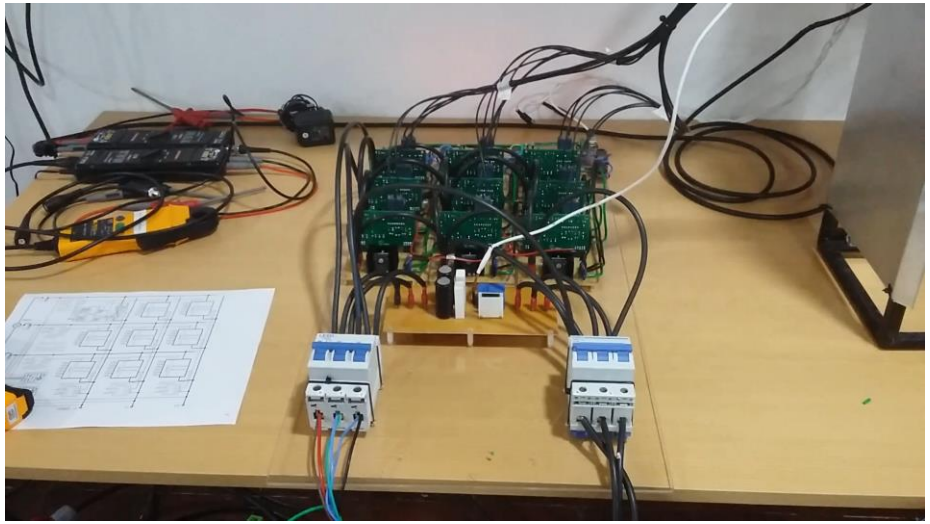




MATRIX CONVERTERS: EXPERIMENTAL SETUP

Desarrollo e implementación de nuevas topologías de convertidores para la interconexión a red de sistemas de generación basados en Energías Renovables





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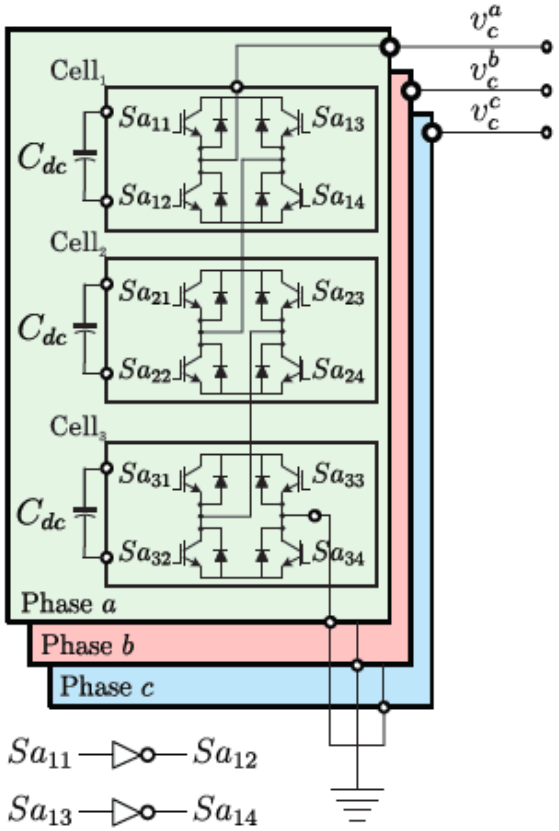
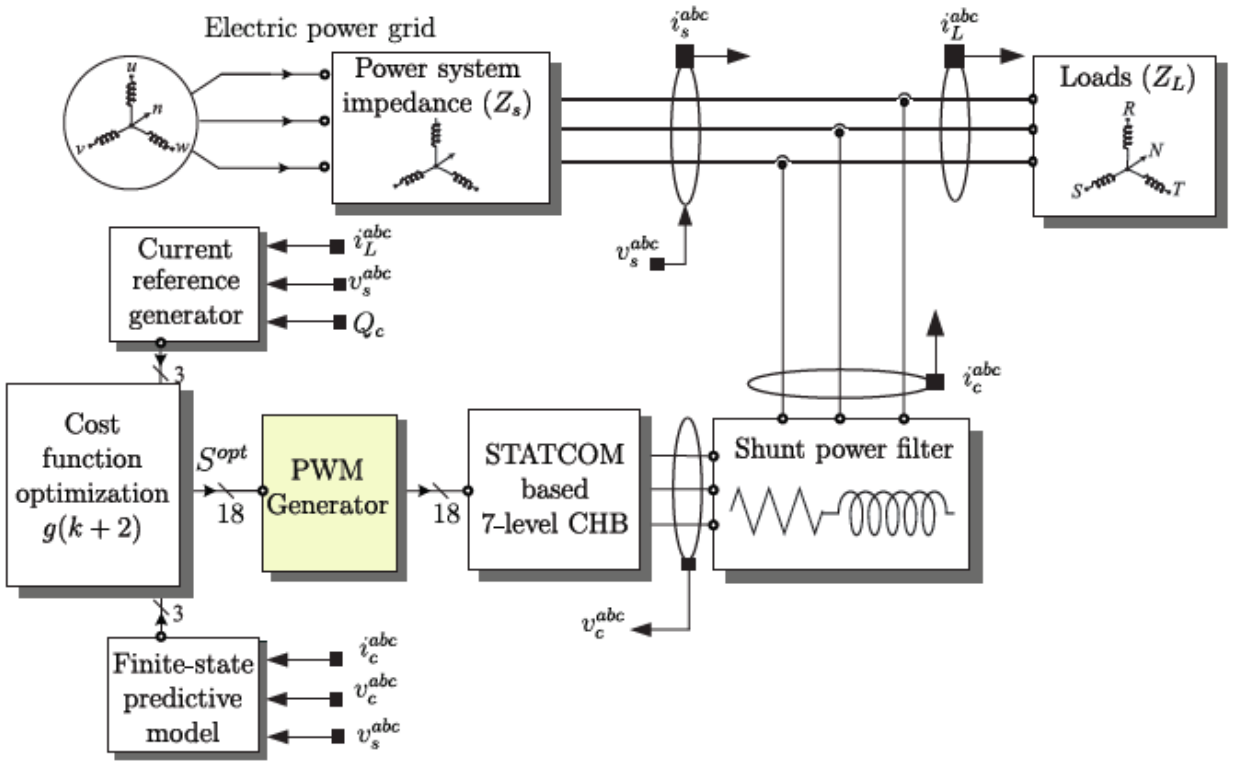
FCS-MPC IN MULTILEVEL/2L CHB APF



(a) Three-phase 7-level CHB converter.

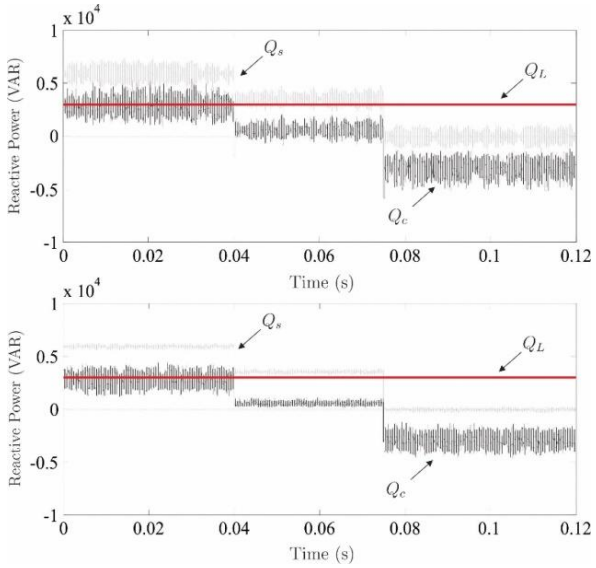


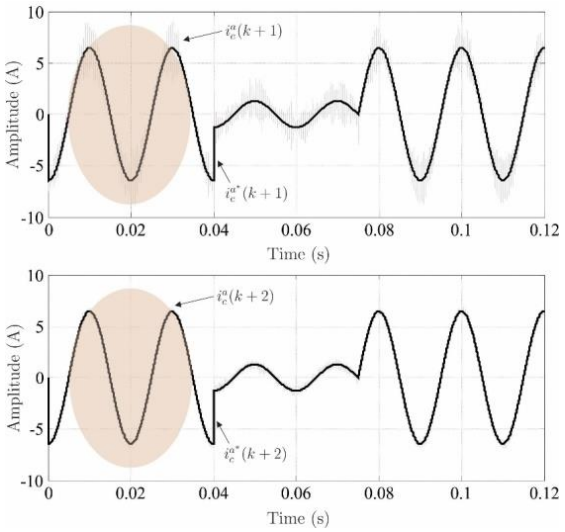
(b) Proposed finite-fixed predictive control technique scheme.

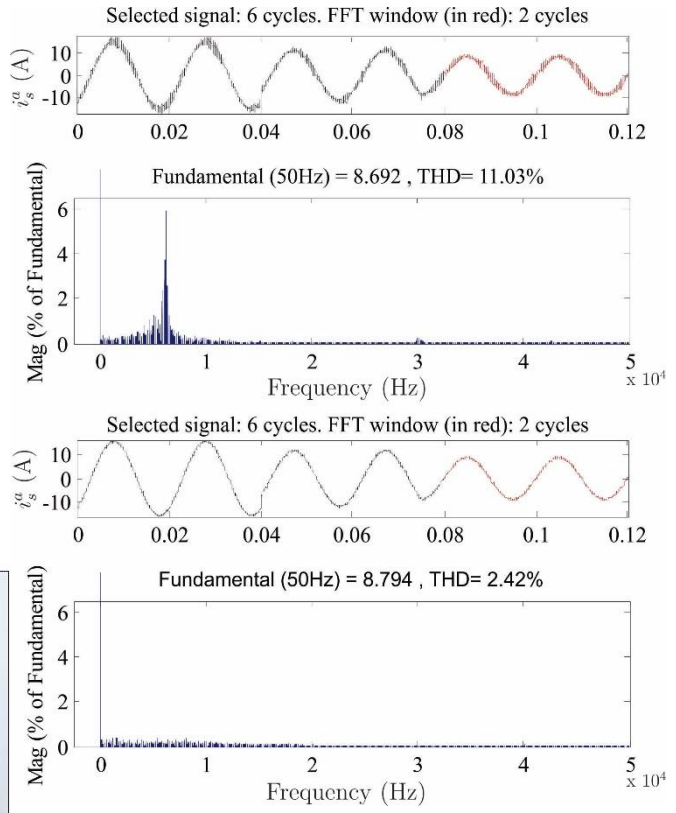
L. Comparatore, J. Rodas, M. Rivera, R. Gregor, J. Pacher, J. Muñoz, P. Sanjeevikumar, "**Model Based Predictive Control with a Fixed Switching Frequency Applied to a Single-Phase Cascade H-Bridge Multilevel STATCOM**," *IEEE Conference on Industrial Electronics and Applications: ICIEA 2017 , Siem Reap, Combodia, Jun. 18-20, 2017.*

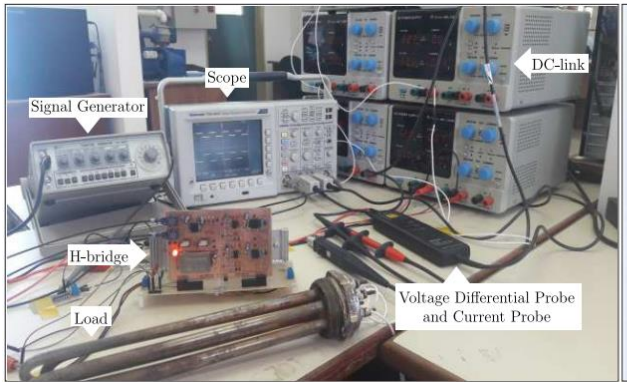
L. Comparatore, J. Rodas, R. Gregor, M. Rivera, "**Model Based Predictive Current Control for a Three-Phase Cascade H-Bridge Multilevel STATCOM Operating at Fixed Switching Frequency**" *IEEE 8th International Symposium on Power Electronics for Distributed Generation Systems: PEDG , Florianopolis, Brazil, April 17-20, 2017.*

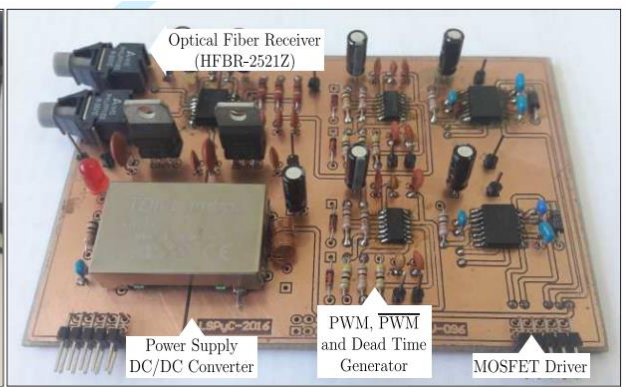
FCS-MPC IN MULTILEVEL/2L CHB APF











L. Comparatore, J. Rodas, R. Gregor, M. Rivera, "Modulated Model Based Predictive Control with Switcher of Redundant States for a Three-Phase Cascade H-Bridge Multilevel STATCOM," *The 18th IEEE Workshop on Control and Modeling for Power Electronics: IEEE COMPEL 2017, Stanford, California, USA, July 9-12, 2017.*

CIENTIFIC CONTRIBUTIONS

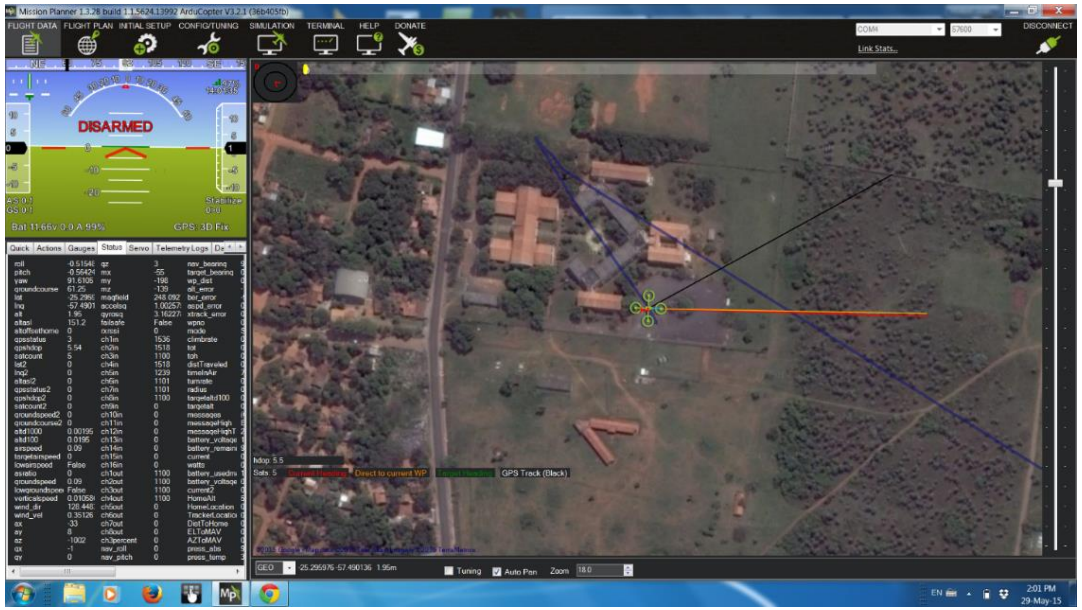
✓ Contributions:

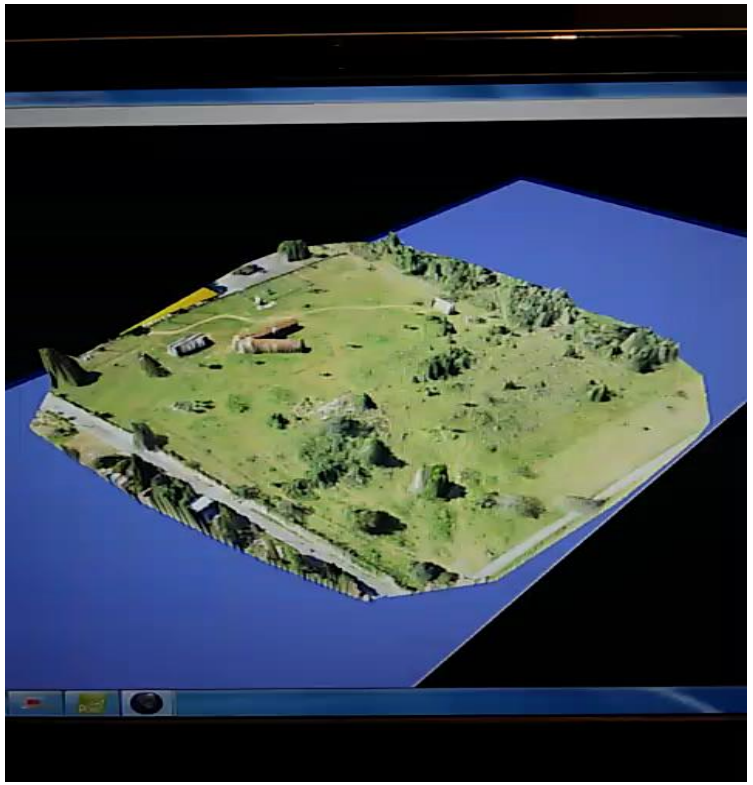
> 20 Journal papers (>7 in IEEE-Trans. Ind. Electronics (Impact Factor: 7.168).

> 70 Conference papers > 3 book's chapters > 30 national conference participation.

FUTURE PROJECTS

Vehículos aéreos no tripulados (UAV) en aplicaciones de fotogrametría para el análisis planialtimétrico y cálculo de volumen





A. Segales, R. Gregor, J. Rodas, D. Gregor, S. Toledo, "**Implementation of a Low Cost UAV for Photogrammetry Measurement Applications**," *ICUAS , Arlington, VA, United States, pp. 1–7, Jul. 07-10, 2016.*

RESEARCH IN POWER ELECTRONICS AND CONTROL

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