# XSICEL 2021

Transición energética en la 4ta revolución industrial

Universidad Tecnológica de Pereira

UNIVERSIDAD NACIONAL DE COLOMBIA

XSICEL 2021

Transición energética en la 4ta revolución industrial

# Synchronization of isolated microgrids with renewable energy sources under distorted voltages

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# I. Introduction

# Motivation

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- Colombia is a privileged country in terms of wide access to natural resources.
- High levels of solar radiation are complemented with richness of hydraulic resources spread all over the country.
- Particular features of local geography makes difficult to provide electricity to communities at certain rural zones.
- In isolated (i.e. non interconnected) areas it is typical the use of low-power generator-sets to attend electric power demand.

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- Reasons motivating the latter include the need of technical and technological tools to handle the intermittency and volatility of non conventional energies.
- Poor performance of commercial equipment operating at low power rates (power quality of cheap generator-sets).
- The development of low-cost, microgeneration systems including renewable sources, becomes an interesting topic for R&D projects supporting economical and social development at rural zones.

# II. Isolated microgrid under study

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- Besides the local control of every source, a more complicated situation becomes their parallel interconnection as a grid, requiring a high degree of synchronization.

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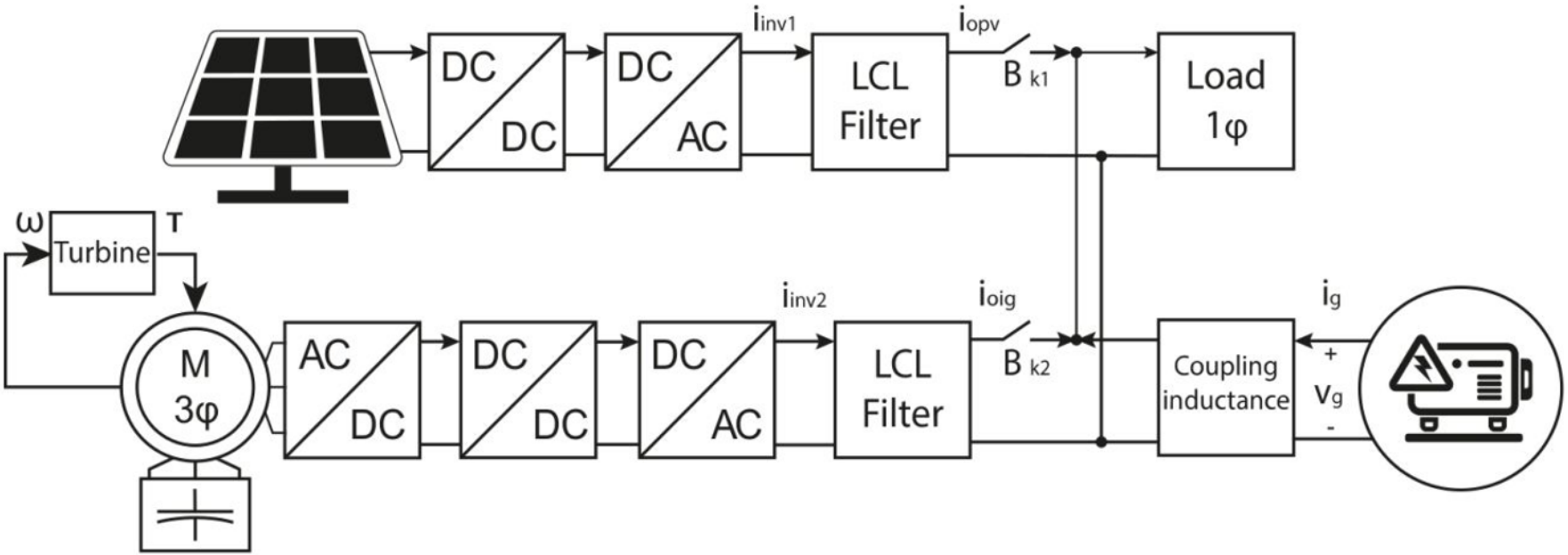

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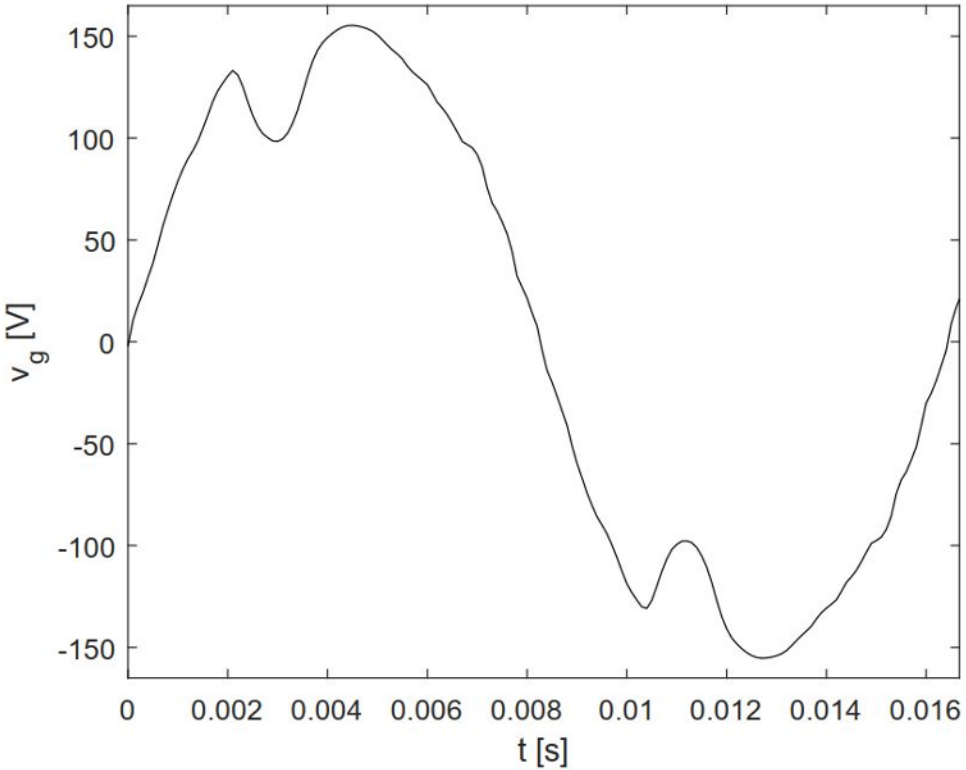

# Problem statement

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**How to achieve synchronization of sources in an isolated microgrid including renewable resources, where the reference generator is a generator-set with harmonic content?**

# The microgrid

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- 1.6 kW, 110 V / 60 Hz single phase, generator-set.
- LCL type filter couplings.

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- Further work is currently developed on a real prototype of the system.

# III. Synchronization strategy

# PLL

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- PLLs were originally developed for applications in telecommunication systems. However, same ideas can be extended to synchronization of power generators.
- A conventional PLL tracks the phase of a sinusoidal signal, assuming there are not variations in amplitude and frequency parameters.
- A robust approach in practice is the so-called Enhanced PLL (EPLL), being able to recover the phase and amplitude of the original sinusoidal signal.

# PLL

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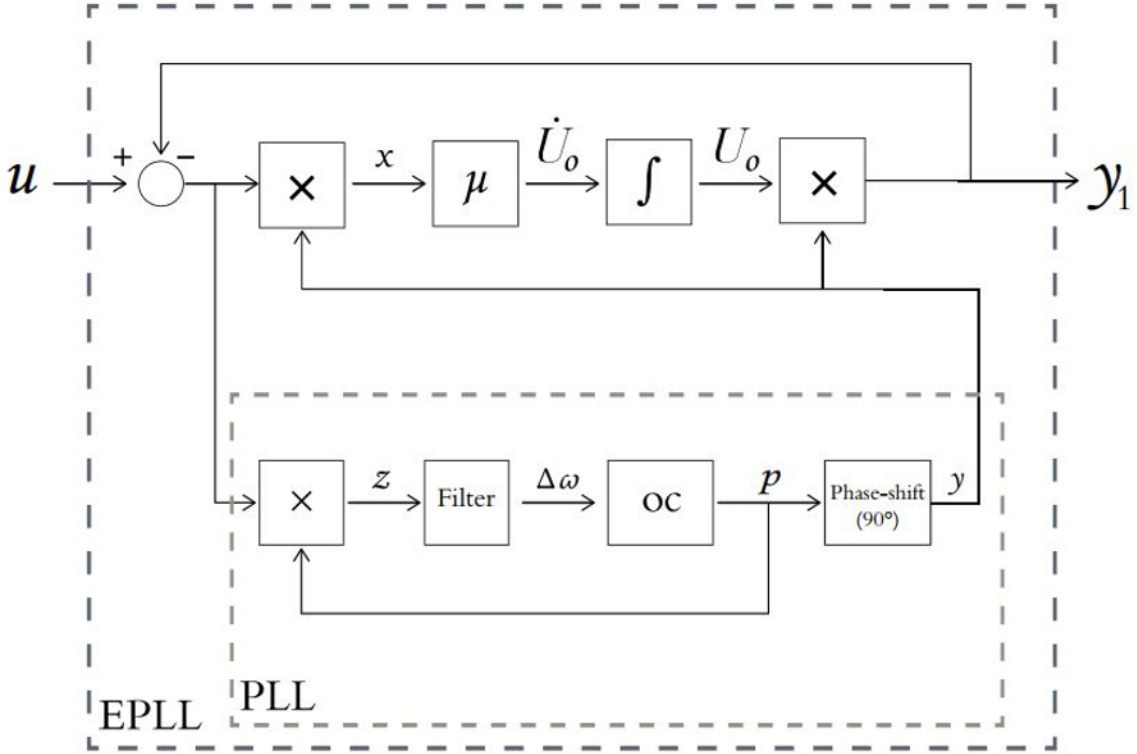

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- Moreover, frequency variations in the reference waveform are captured by the EPLL constituting an adaptive correction for the filter.
- The sinusoidal waveform at the output of the EPLL block is fed as the reference signal of a double-loop resonant controller regulating current and voltage values at the output of each power inverter.

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$$\rho = \frac{\sigma_{V_c V_g}}{\sigma_{V_c} \sigma_{V_g}},$$

being $\sigma_{V_c V_g}$ the covariance of $(V_c, V_g)$, $\sigma_{V_c}$ the standard deviation of $V_c$ and $\sigma_{V_g}$ the standard deviation of $V_g$.

# PLL

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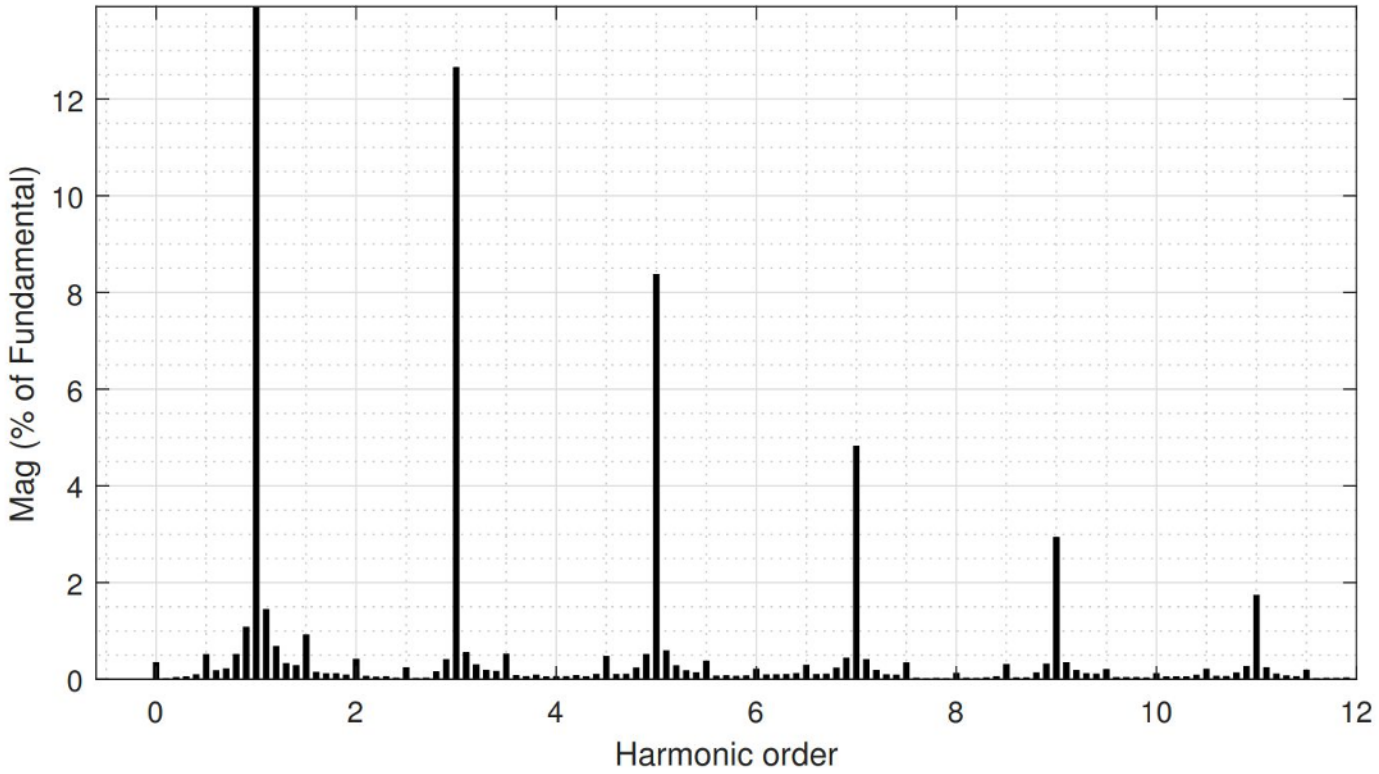

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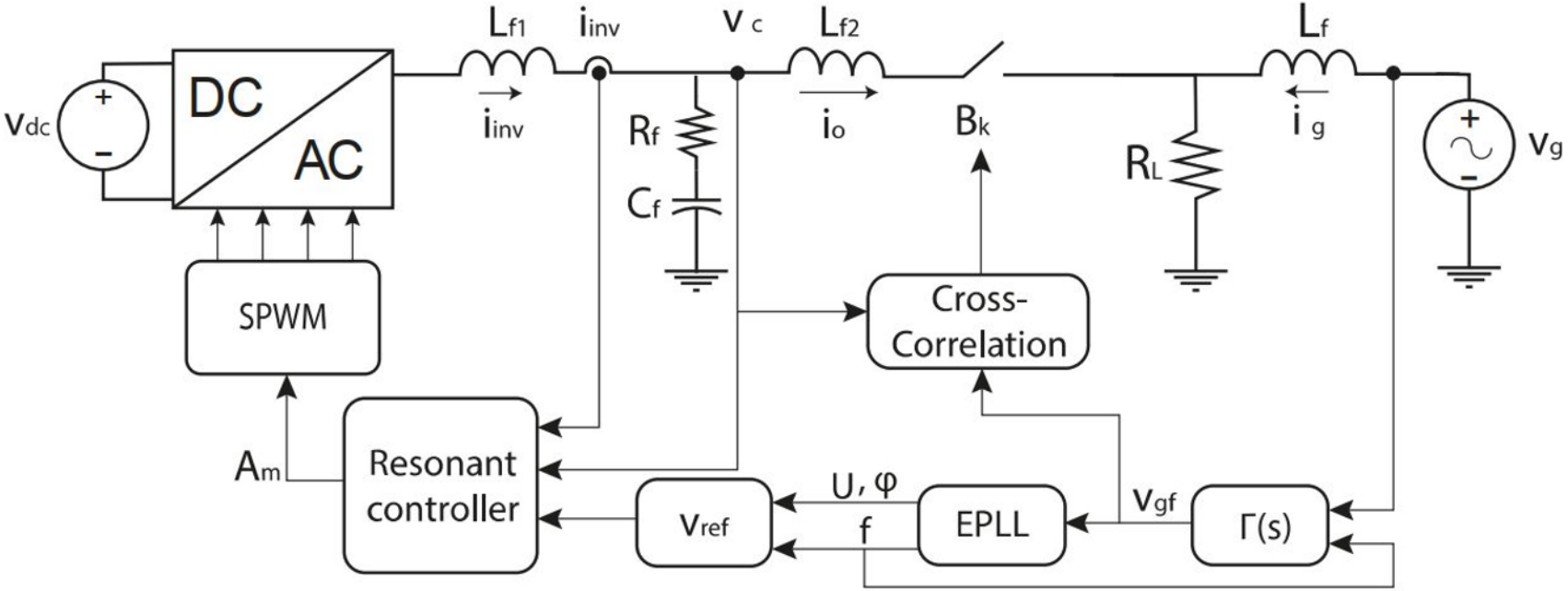
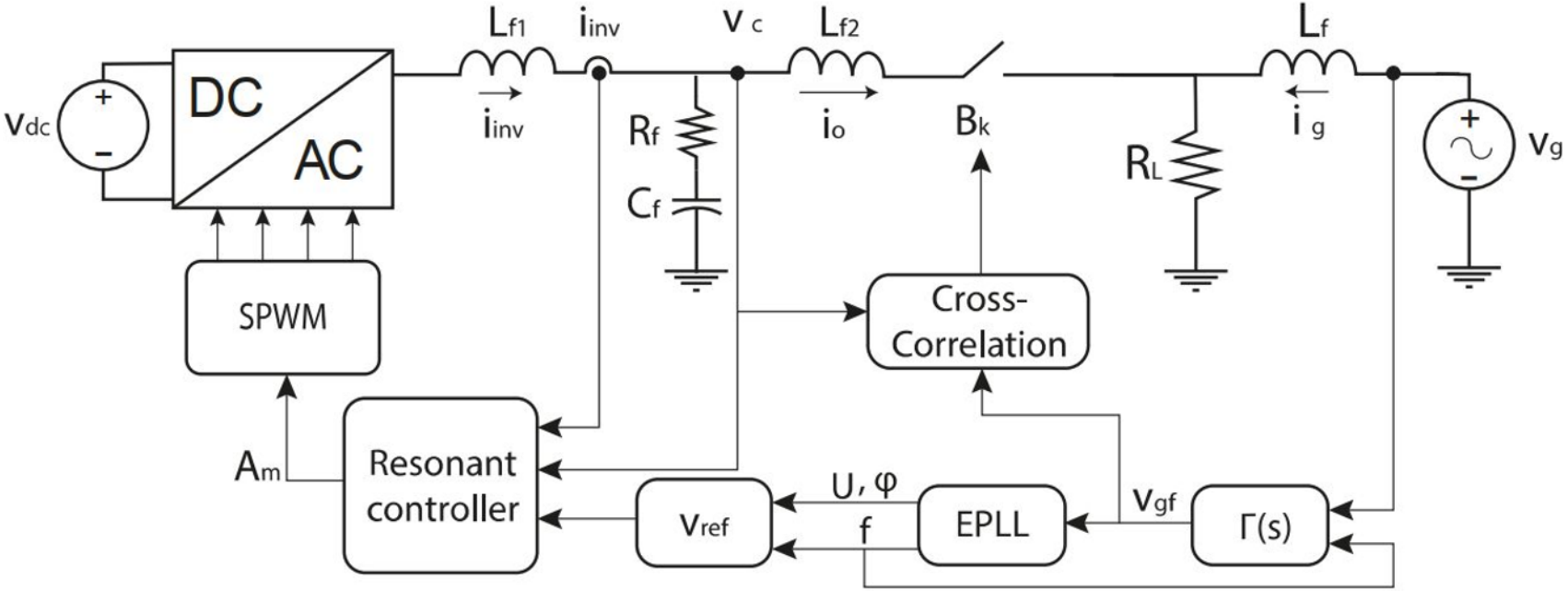

Lf1
iinv
v c
Lf2
Lf
Vdc
DC
AC
iinv
Rf
Cf
io
Bk
RL
i g
Vg
SPWM
Cross-
Correlation
Am
Resonant
controller
U, φ
Vref
f
EPLL
Vgf
Γ(s)

# PLL




$$\Gamma(s) = \frac{ks}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

# IV. Results

# Simulation scenario

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- The synchronization scheme was applied independently to each generator (i.e. photovoltaic and turbine) with respect to the reference generator (i.e. generator-set).
- The general scenario starts at t = 0 with the generator-set feeding a load of 1.5 kW.

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- for t = 3, a perturbation is applied to the reference voltage, altering its amplitude, frequency and phase.
- Results allow to confirm that synchronization is recovered in spite of disturbances.

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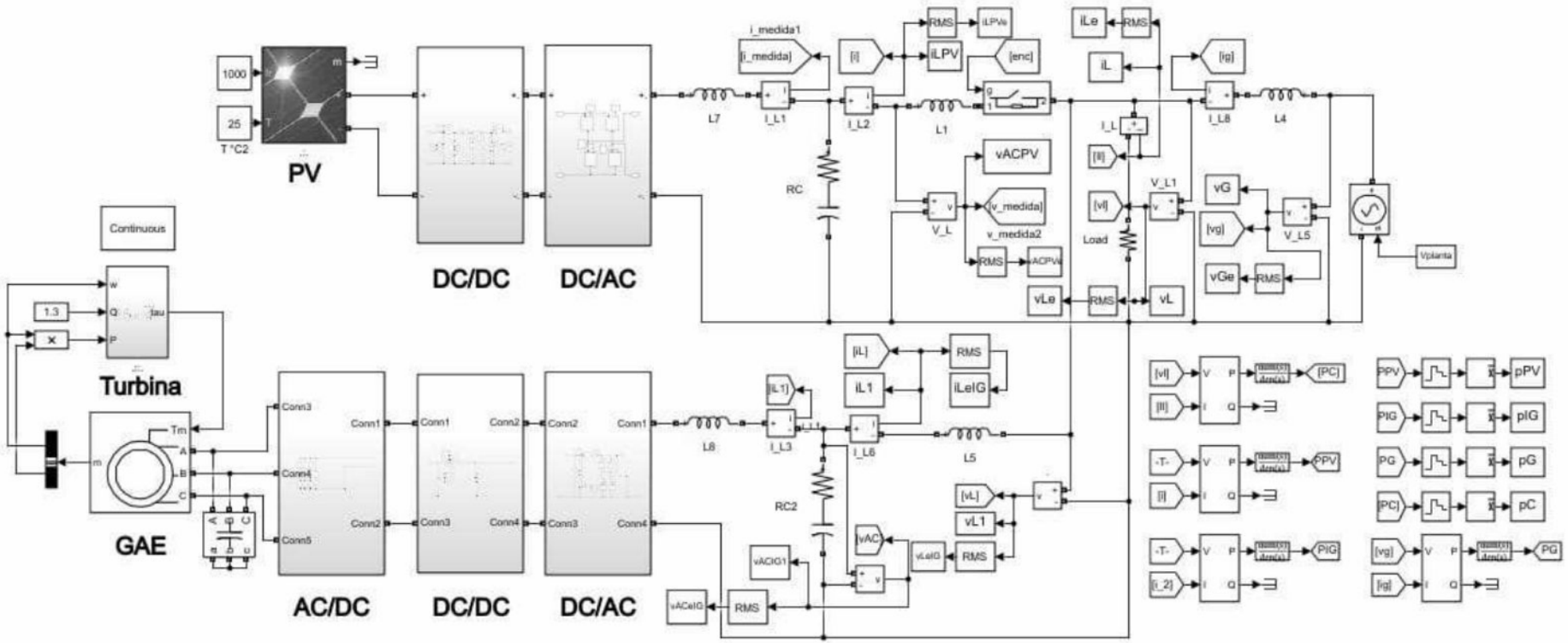

# Power sharing

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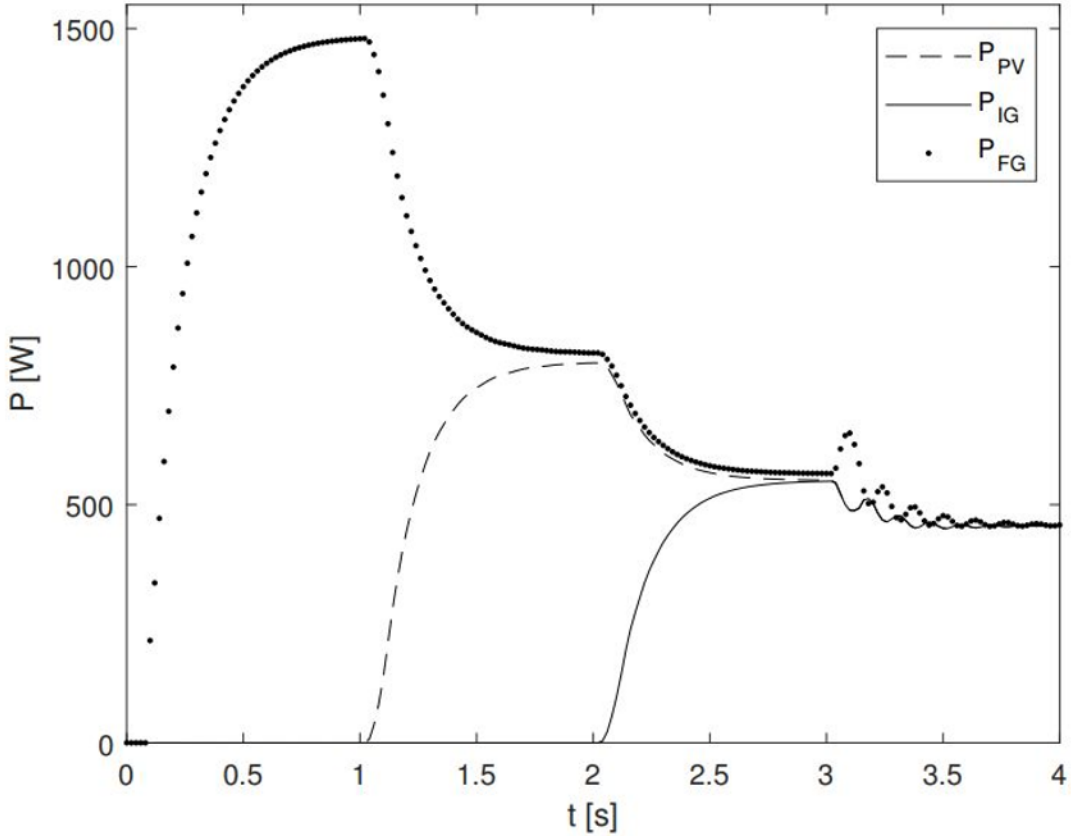

# Filtering

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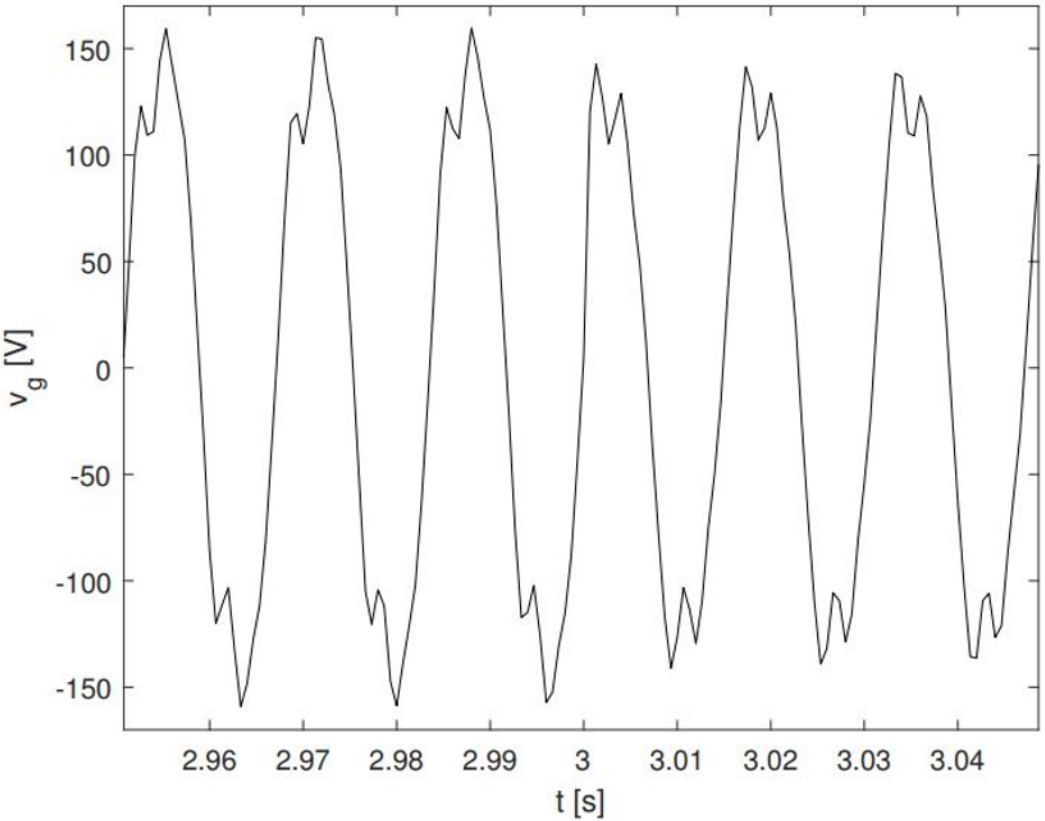

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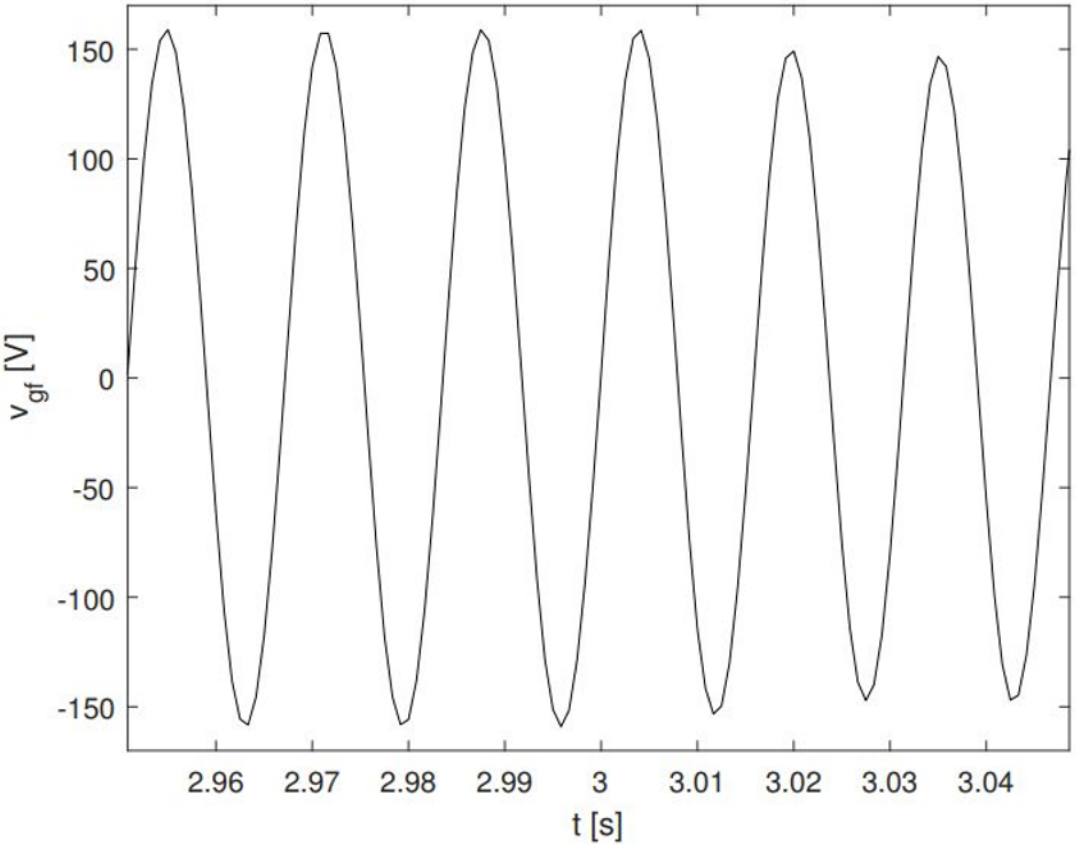

# Parameters

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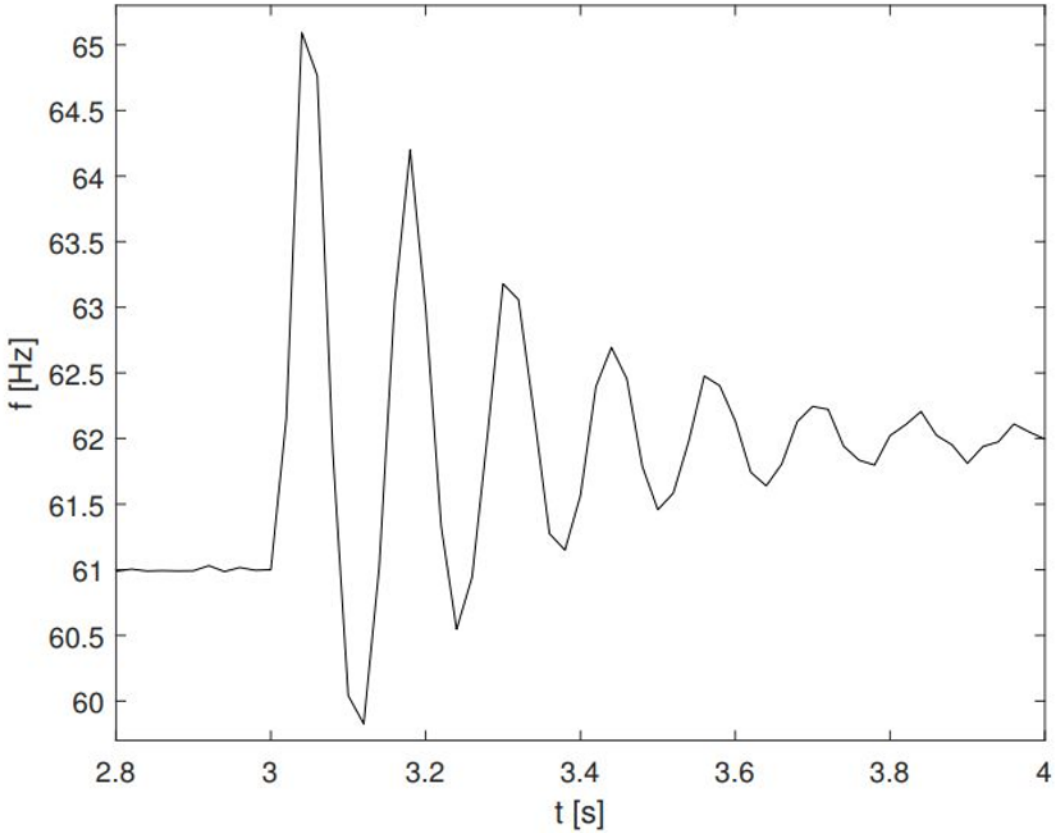

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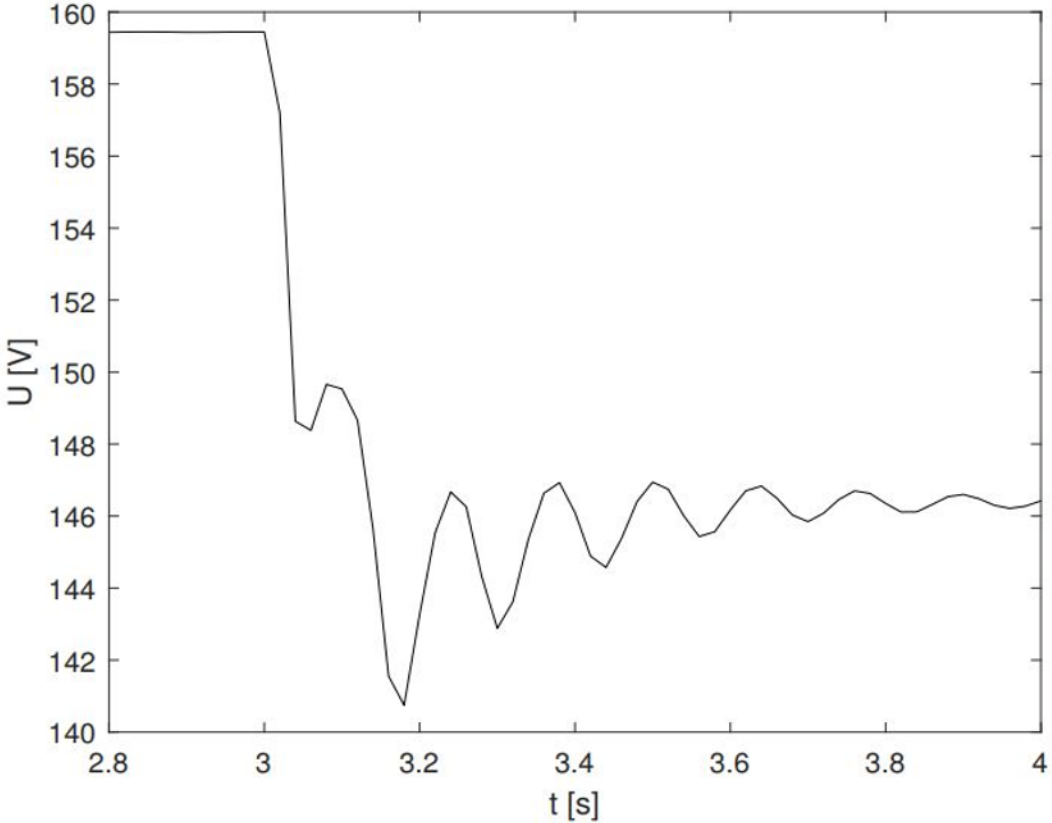

# PV unit

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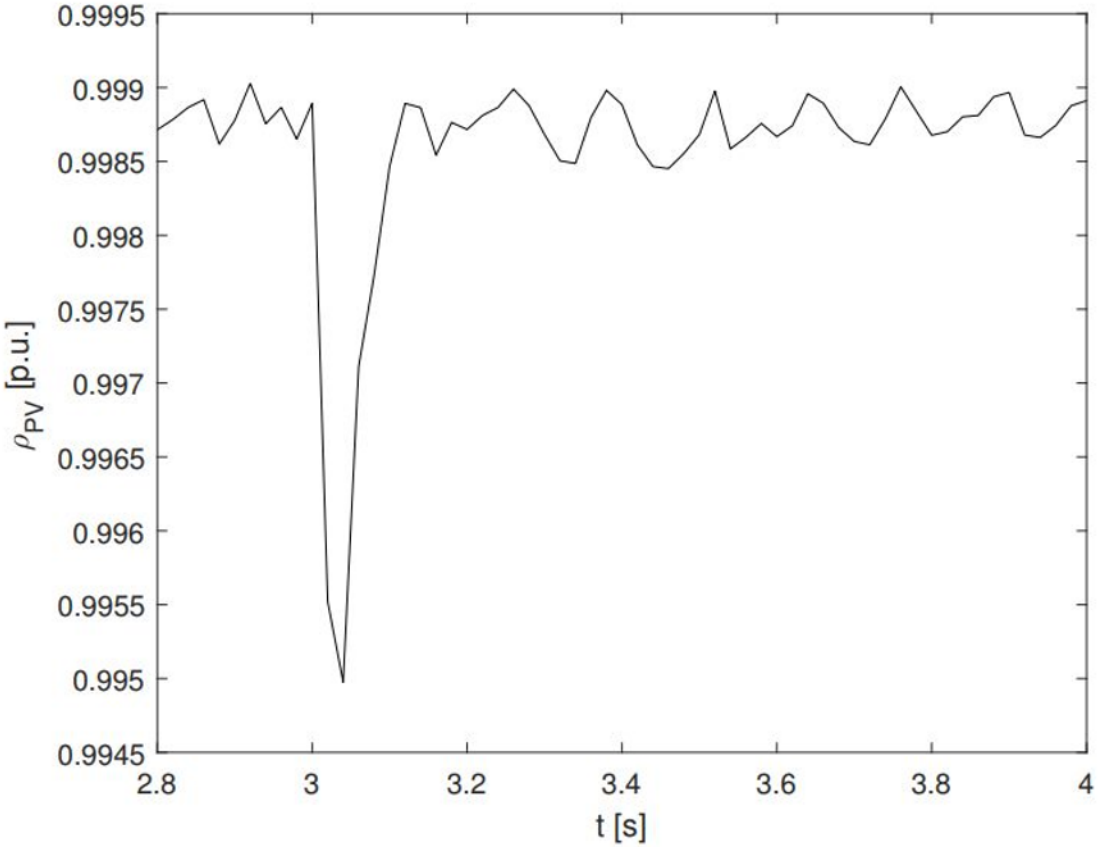
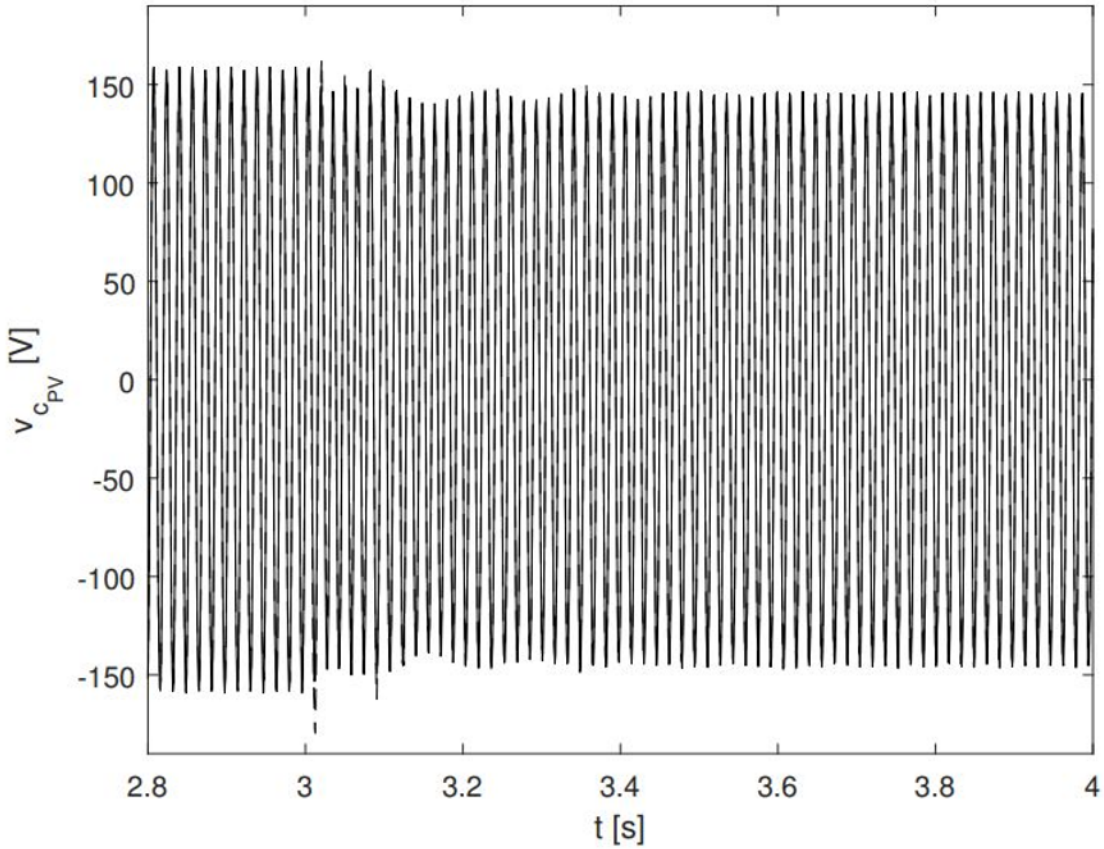

0.9995
0.999
0.9985
0.998
0.9975
0.997
0.9965
0.996
0.9955
0.995
0.9945
$\rho_{PV}$ [p.u.]
2.8
3
3.2
3.4
3.6
3.8
4
t [s]

# PV unit

# PV unit



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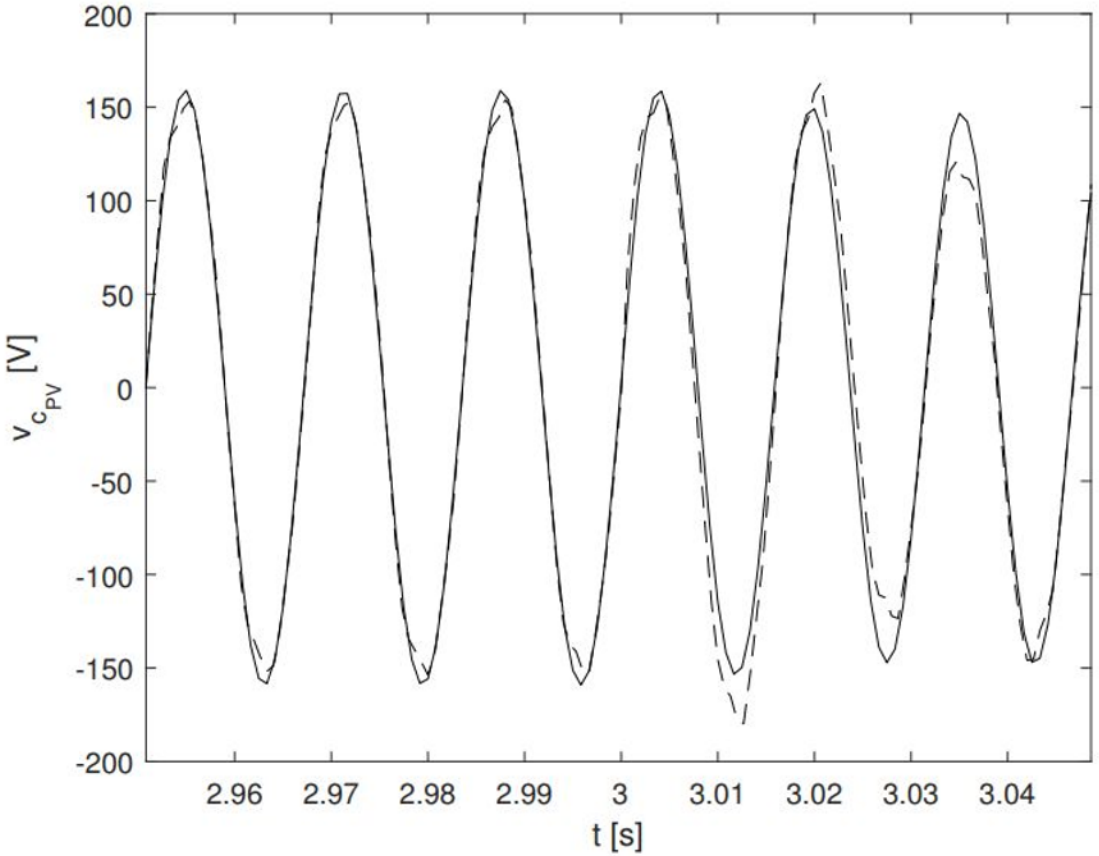
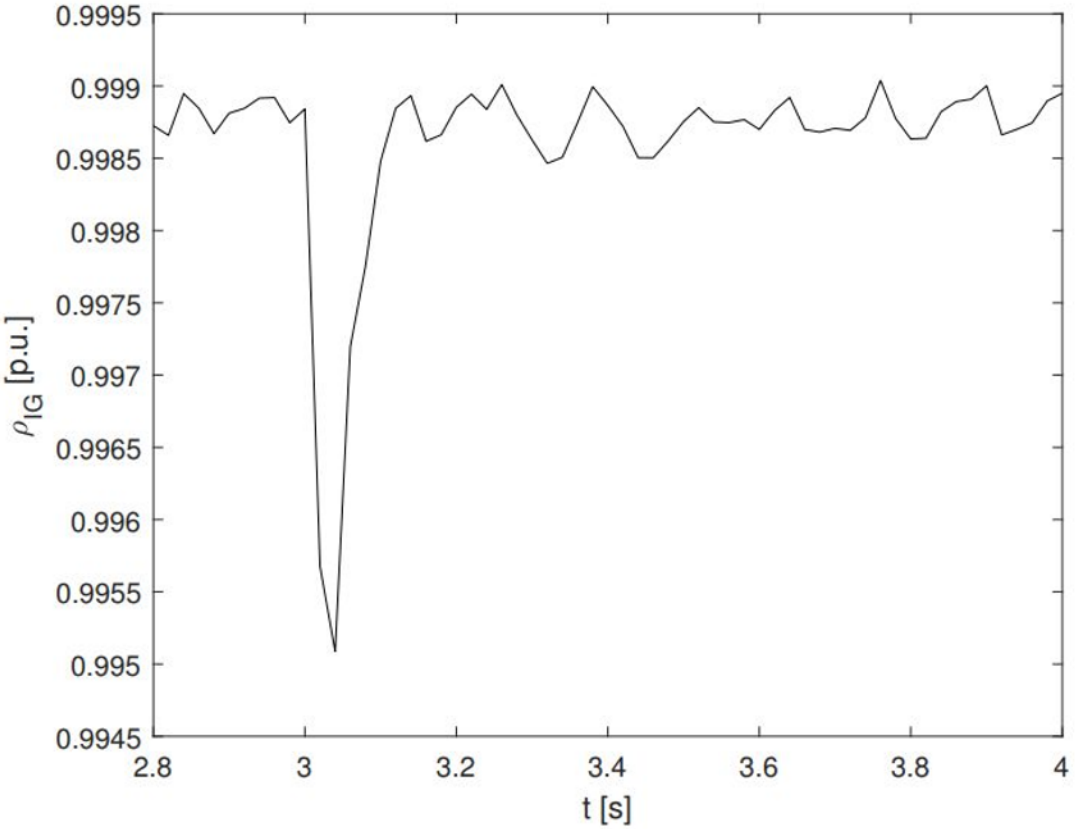

200
150
100
50
0
-50
-100
-150
-200
$v_{c_{PV}}$ [V]
2.96
2.97
2.98
2.99
3
3.01
3.02
3.03
3.04
t [s]

# Turbine

# Turbine


0.9995
0.999
0.9985
0.998
0.9975
0.997
0.9965
0.996
0.9955
0.995
0.9945
$\rho_{IG}$ [p.u.]
2.8
3
3.2
3.4
3.6
3.8
4
t [s]

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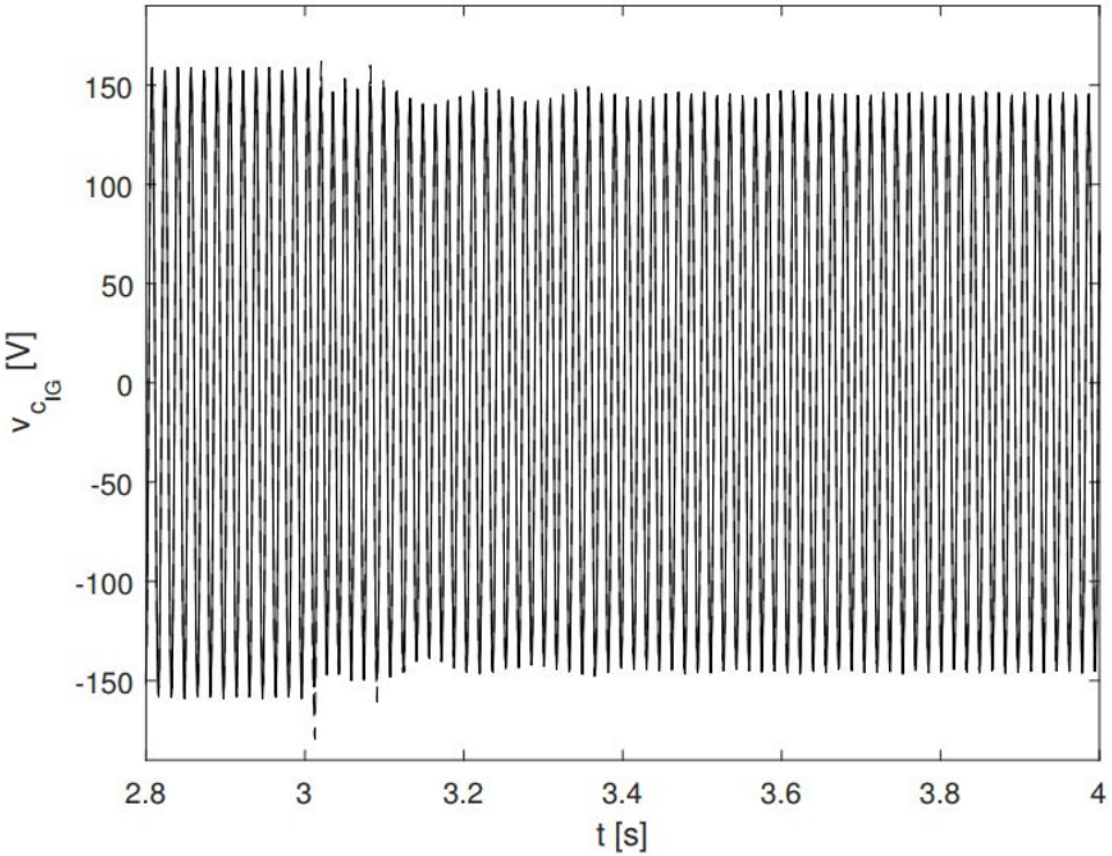
# Turbine



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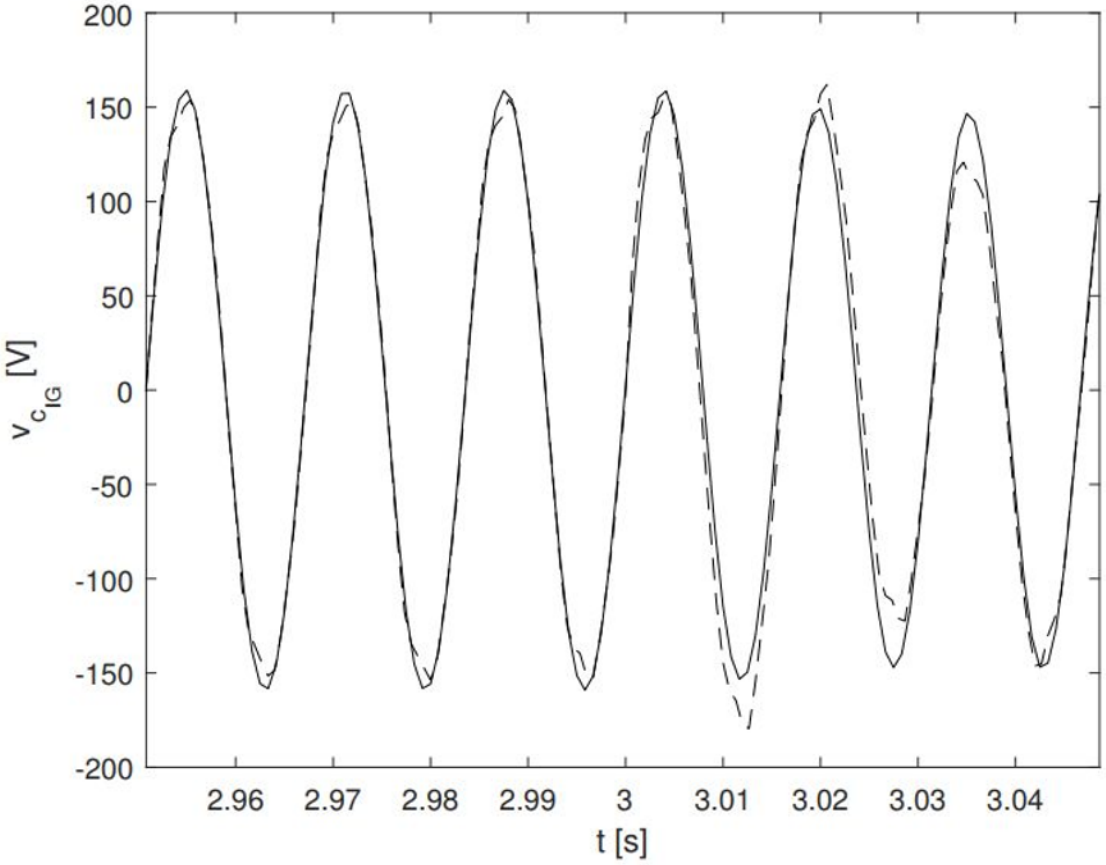
200
150
100
50
0
-50
-100
-150
-200
$v_{c_{IG}}$ [V]
2.96
2.97
2.98
2.99
3
3.01
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3.04
t [s]

# V. Conclusions

# Concluding remarks

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- Simulation results unveiled the robustness of the proposed scheme to disturbances applied to parameters of the voltage reference signal.

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- A synchronization scheme composed of an EPLL, an adaptive bandpass filter and a cross-correlation index, has been proposed to perform interconnection of sources in an isolated microgrid combining renewable resources with a generator-set including harmonic content.
- Simulation results unveiled the robustness of the proposed scheme to disturbances applied to parameters of the voltage reference signal.
- Ongoing work is currently devoted to experimental verification of the proposed synchronization strategy on a laboratory prototype built at the Universidad Industrial de Santander.

# Acknowledgements

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# Questions?

Thank you for your attention !!!

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