Faculty of Electrical Engineering

WARSAW UNIVERSITY OF TECHNOLOGY

EPE'18 ECCE EUROPE

20TH EUROPEAN CONFERENCE ON POWER ELECTRONICS AND APPLICATIONS

On the similarity and challenges of multiresonant and iterative learning current controllers for grid converters under frequency fluctuations and load transients

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What I'm going to discuss

- Resonant (MOSC), repetitive (RC) and iterative learning controllers (ILC)
- Grid interface for an energy storage as a case study
- Similarities and challenges
- Adaptive damping and conditional learning as two counterparts
- Some results and conclusions

MOSC, RC and ILC all introduce the same generating polynomial

$$G_{\mathrm{MOSC}}(s) = \frac{k_0}{s} + \sum_{n=1}^{\infty} \frac{k_n s}{\left(\frac{s}{n\omega_1}\right)^2 + 1} = \frac{N_{\mathrm{MOSC}}(s)}{s \prod_{n=1}^{\infty} \left(\left(\frac{s}{n\omega_1}\right)^2 + 1 \right)}$$

$$G_{\mathrm{ILC}}(s) = \frac{k_{\mathrm{ILC}}}{e^{\frac{2\pi s}{\omega_1}} - 1} = \frac{N_{\mathrm{ILC}}(s)}{s \prod_{n=1}^{\infty} \left(\left(\frac{s}{n\omega_1}\right)^2 + 1 \right)}$$

They suffer from quite the same suite of problems, e.g. innate lack of robustness, bad transients and not-so-obvious state limiting algorithms (anti-windup algorithms).

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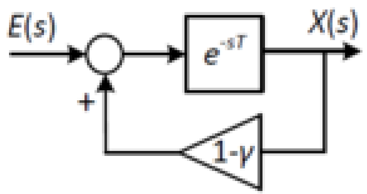

ILC vs. MOSC

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Iterative learning controller (ILC) versus multioscillatory controller (MOSC) battle.

I highly encourage you to experiment with the above model and read an included companion journal paper prior to experimenting with the conditional learning concept.

The system

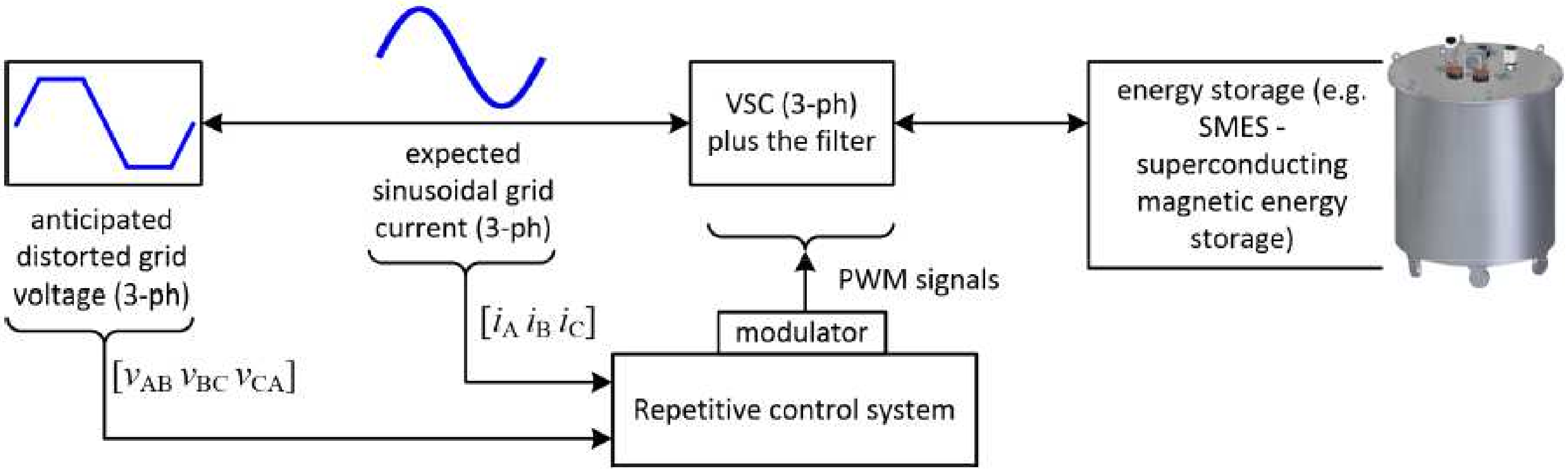
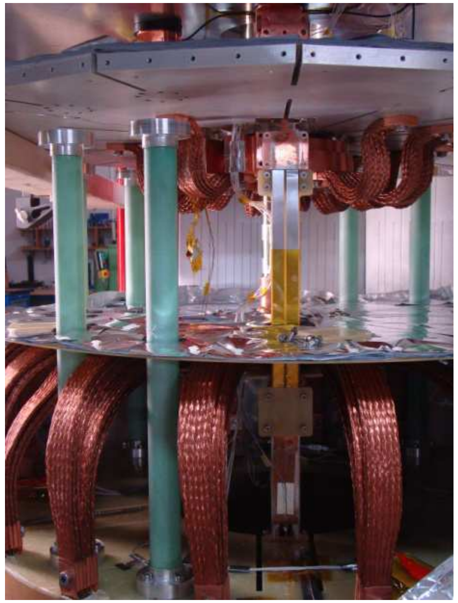


Fig. 1: A grid-tie converter interfacing an energy storage



The classic approach

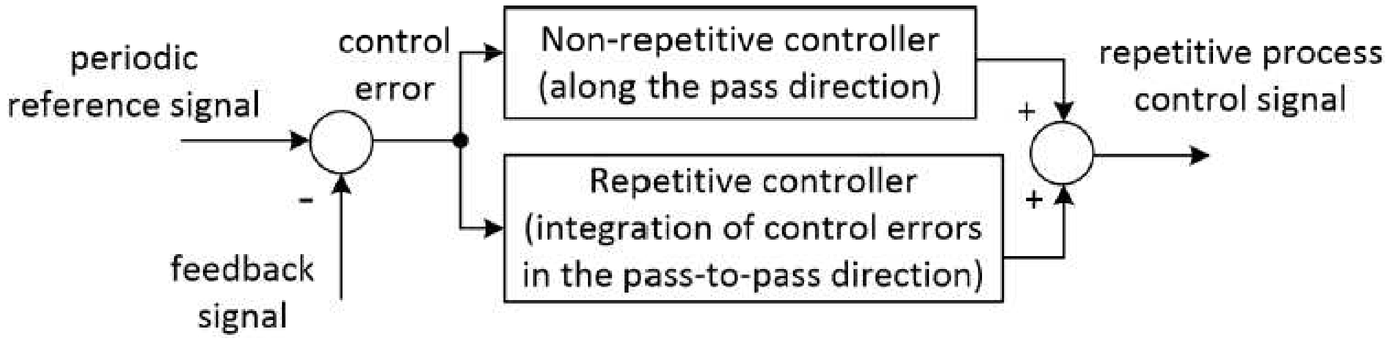


Fig. 2: A classic approach to iterative learning control: the repetitive controller is plugged into a non-repetitive control system without any additional algorithms whose execution would be triggered or suppressed by the response shaped by the non-repetitive part of the control system

$$u(k+1,p) = Q_{\mathrm{LPF}}(z)Q_{\mathrm{FD}}(z)u(k,p) + k_{\mathrm{RC}}e(k,p+1)$$

Our approach

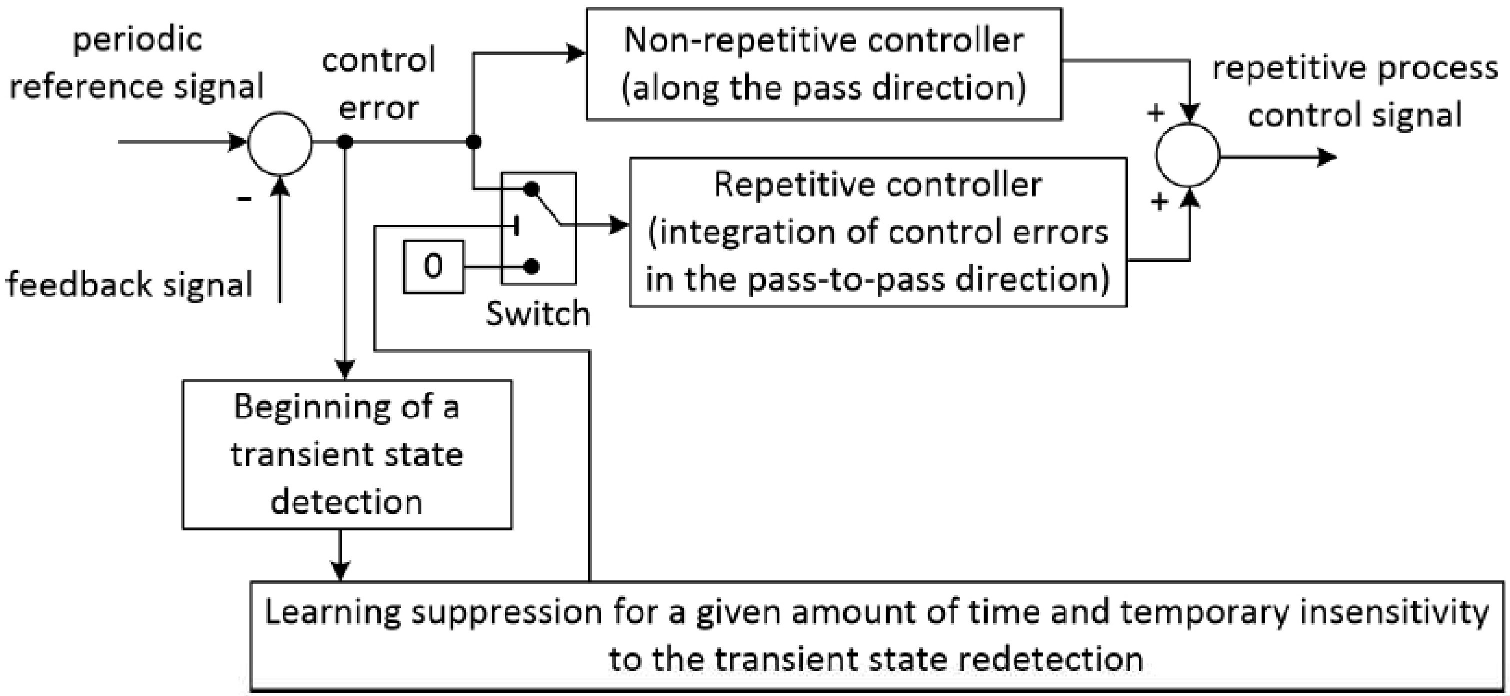


Fig. 5: Proposed approach to iterative learning control: the repetitive controller is plugged into a non-repetitive control system with an additional algorithm whose execution is triggered or suppressed by the response shaped by the non-repetitive part of the control system

The difference

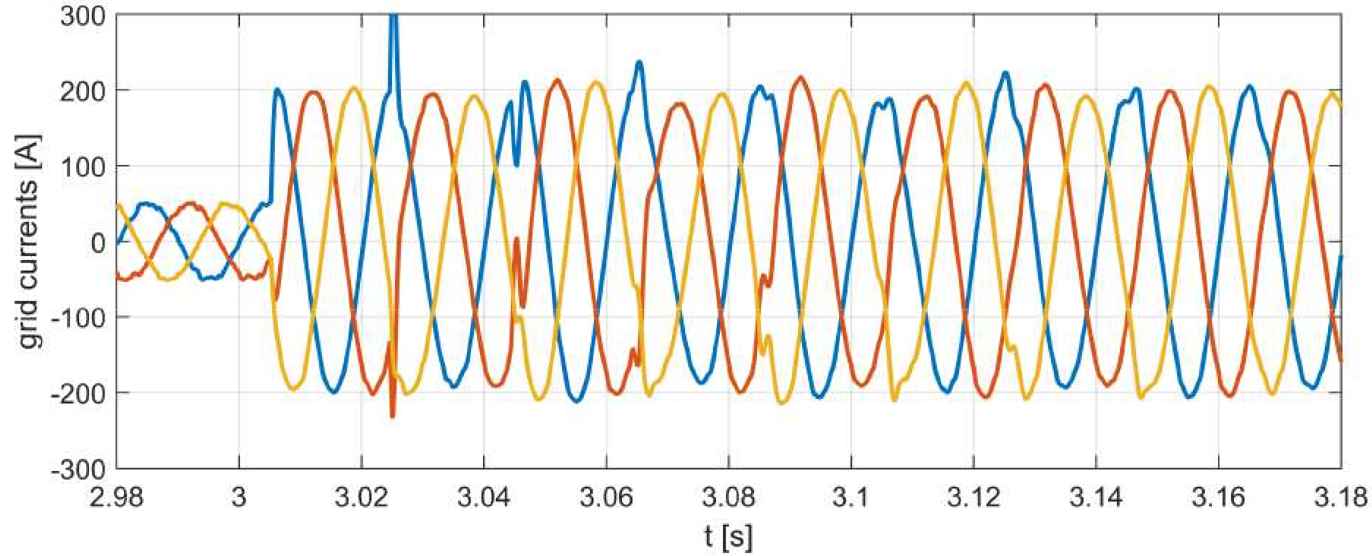


Fig. 6: Transients caused by the step load (from 25% to 100% of nominal load) if constant forgetting is assumed

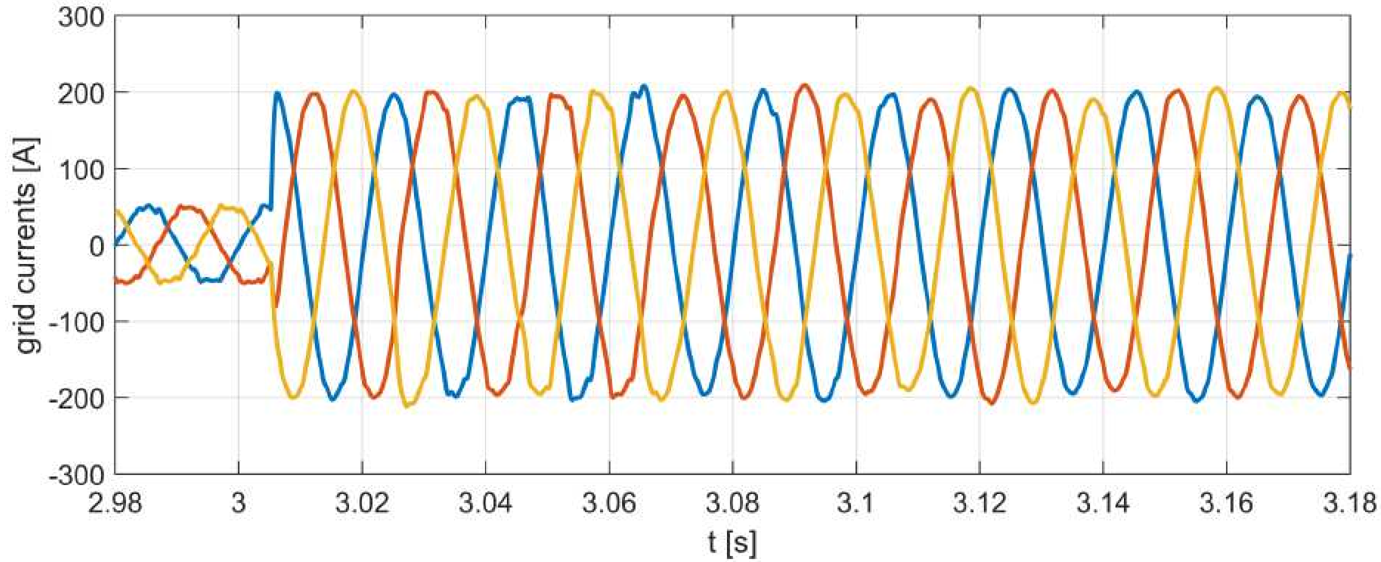


Fig. 7: Transients caused by the step load (from 25% to 100% of nominal load) if adaptive forgetting is assumed (to be compared with Fig. 6)

Key analogies and the missing piece

Table I: MOSC versus ILC modifications

Problem	Possible solution to MOSC	Possible solution to ILC
Robustness to prevailing non-zero error	damping $\zeta > 0$ in (6)	forgetting factor $\gamma > 0$ in (4)
Selectiveness	by zeroing selected $k_\bullet$ in (1)	by designing an appropriate Q in (5)*
System phase lag compensation	correction of zeros as in [6] with corrections in [7]	replacing $e(k, p+1)$ in (5) with $e(k, p+p_0)$, where $p_0 \geq 1$, as in [23]
Resonant frequency matching when discretizing	the bilinear transform with pre-warping [1] or other frequency warping algorithms [6]	ILC design procedure starts already in the discrete time domain
Robustness to grid frequency fluctuations	innate due to $\zeta > 0$; can be strengthened by pole adaptation based on PLL/FLL	adaptive fractional delay filter [16]
Anti-windup (oscillatory state limiting)	adaptive damping ζ in (6)	conditional learning – the concept proposed herein

$*$ usually Q is designed as an LPF; however, more intricate designs can be envisaged to mimic the selectiveness easily achievable in the MOSC

The model at your disposal

Thank you for having me!

„I'm always open for people saying I'm wrong because most of the time I am." Prince William

The National Centre for Research and Development

Program Badań Stosowanych

Acknowledgments

The research was supported by the National Centre for Research and Development (Narodowe Centrum Badan i Rozwoju) within the project No. PBS3/A4/13/2015 entitled "Superconducting magnetic energy storage with a power electronic interface for the electric power systems" (original title: "Nadprzewodzacy magazyn energii z interfejsem energoelektronicznym do zastosowan w sieciach dystrybucyjnych"), 01.07.2015–31.12.2018. The acronym for the project is NpME.