



SPS Main Power Converters Noise & Regulation

Joint Accelerator Performance 2024 Workshop

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Content

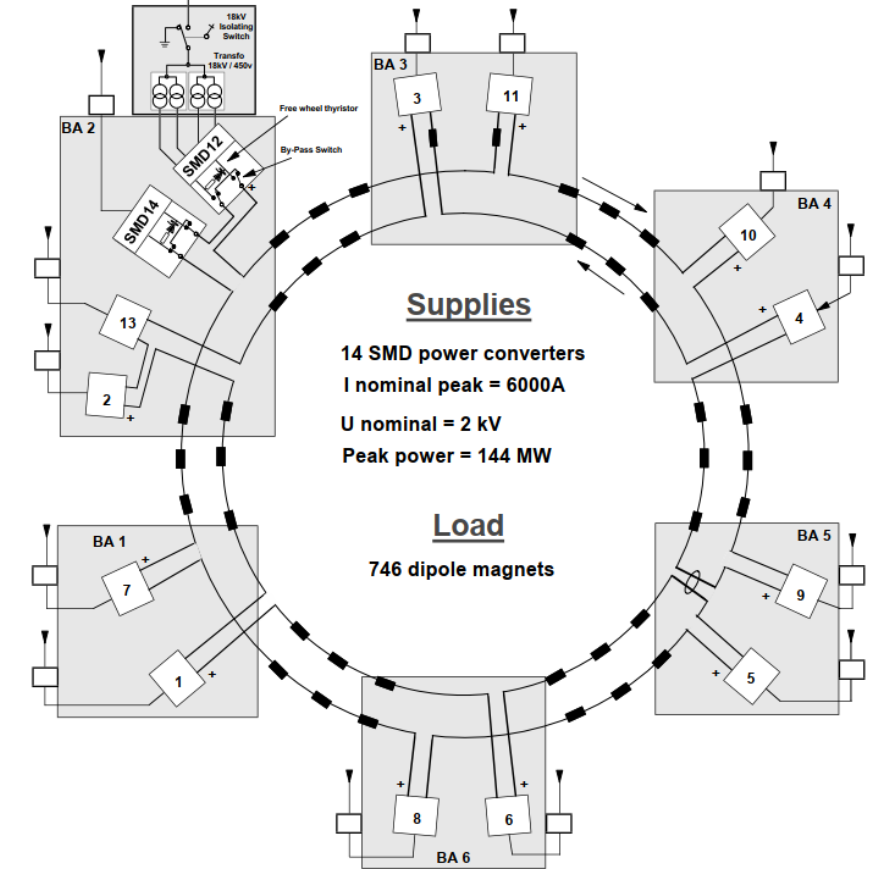
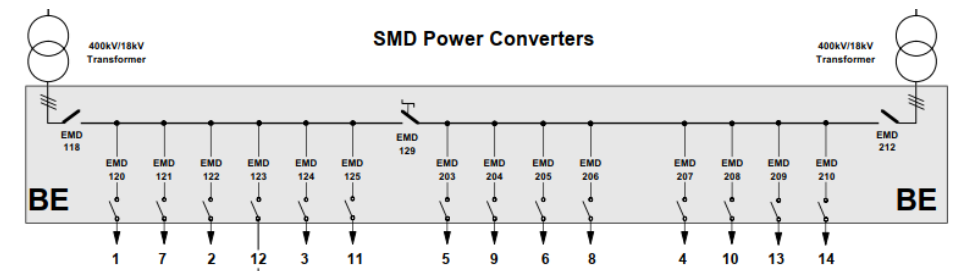
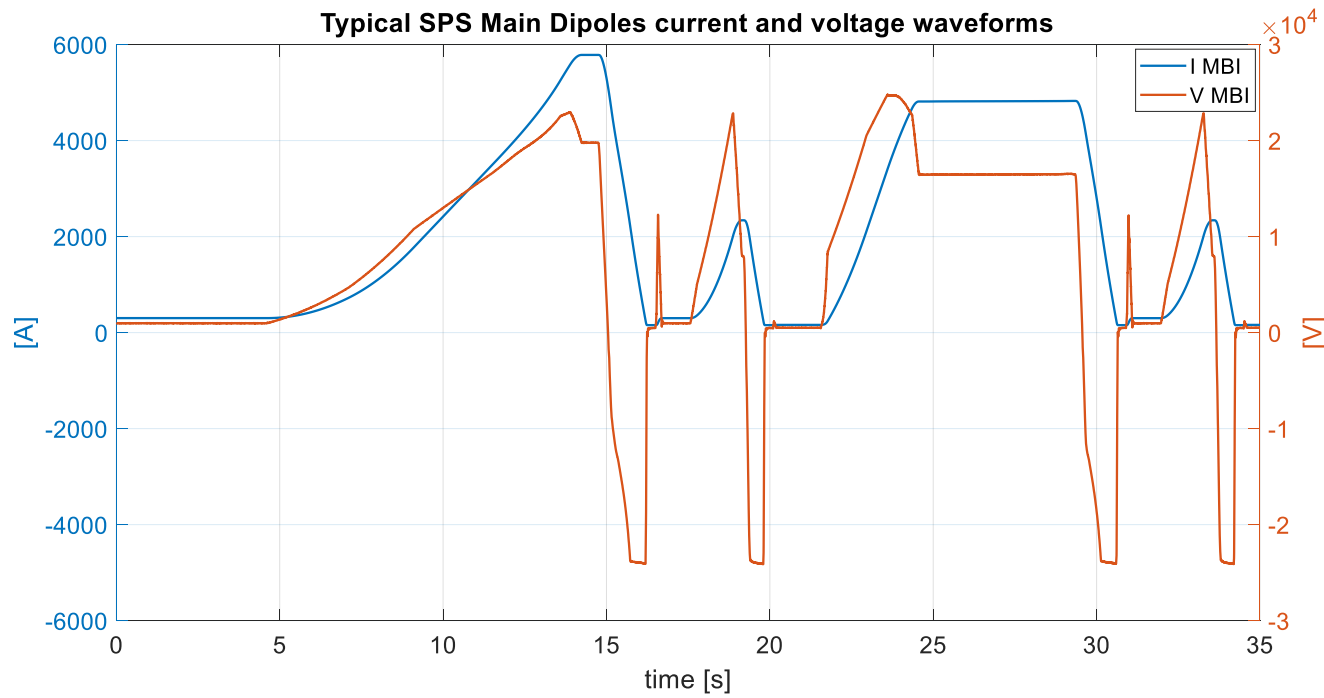
1. SPS main power converters overview
2. SPS mains ripple and compensation measures
3. Regulation overshoots and possible mitigations
4. Current glitches and improved diagnostics

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1. **SPS main power converters overview**
2. SPS mains ripple and compensation measures
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4. Current glitches and improved diagnostics

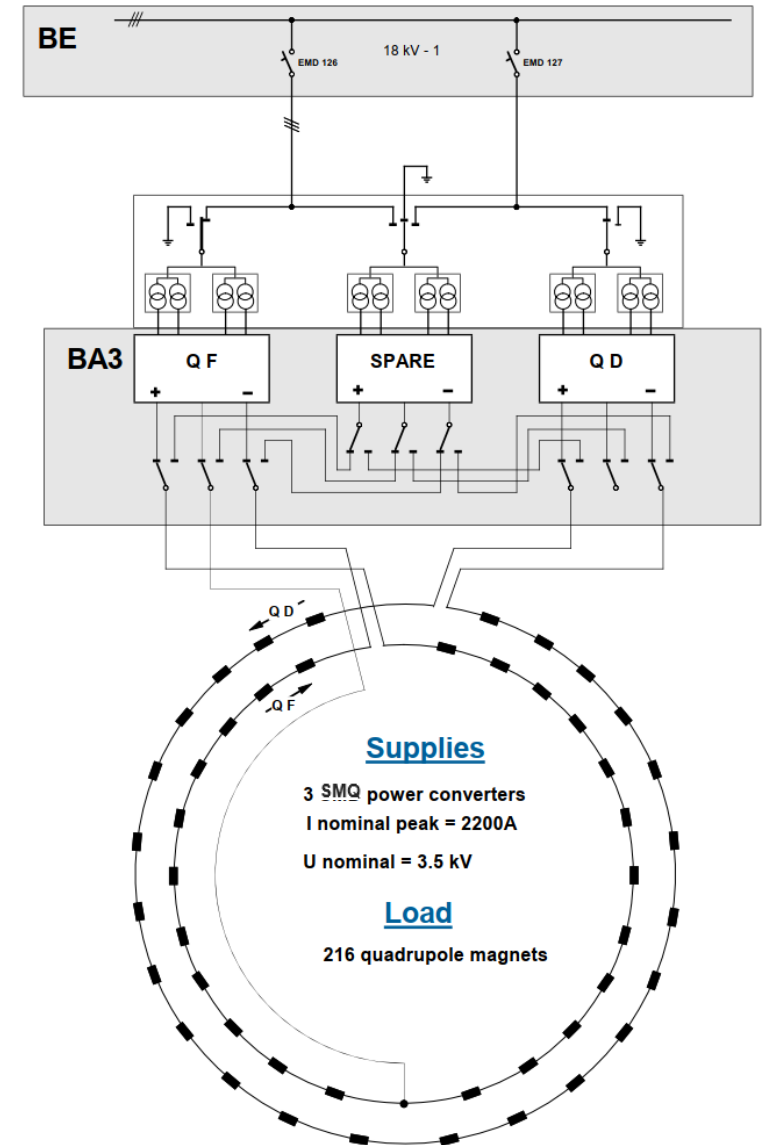
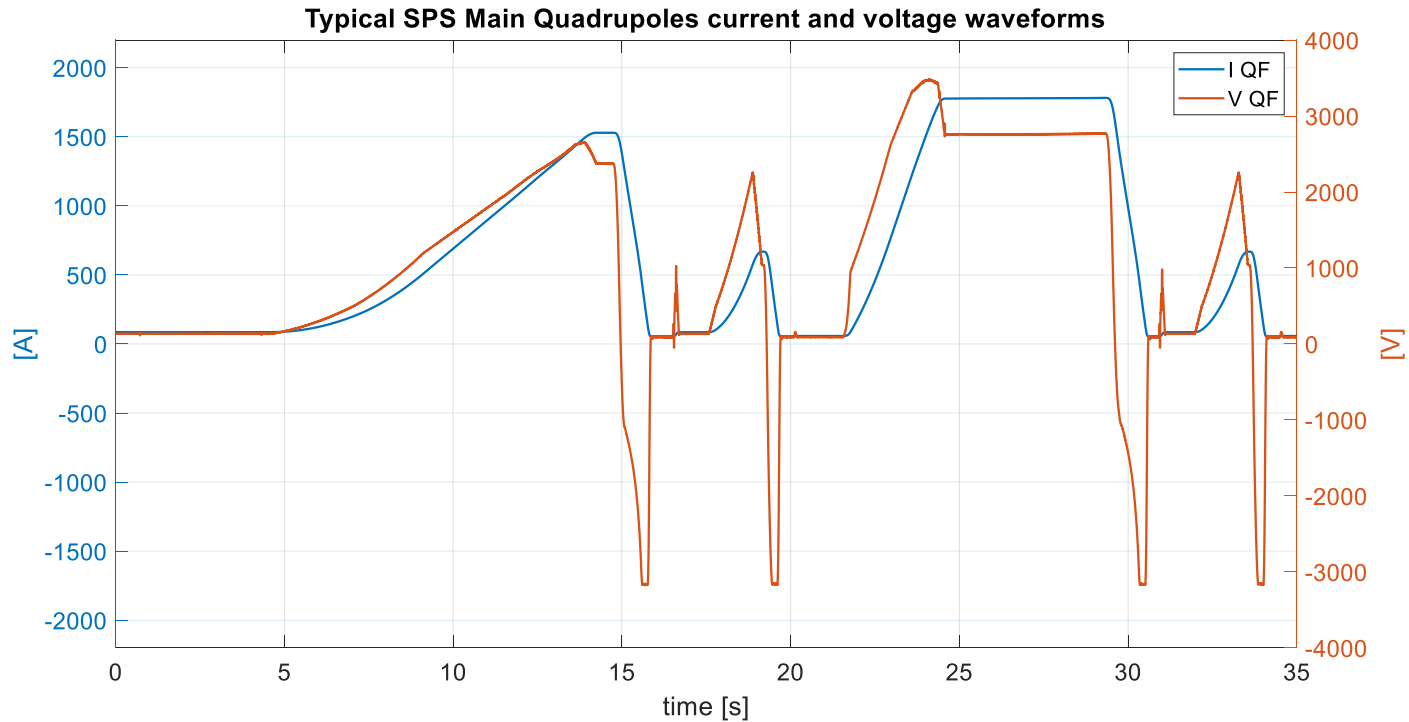
SPS main dipoles overview

- Ratings: 6 kA / 25 kV, < 20 ppm
- 12 SMD stations **in series** + 2 spares
- 1 **common digital** current regulator (FGC3)
- **Analogue** voltage regulation and firing in each SMD



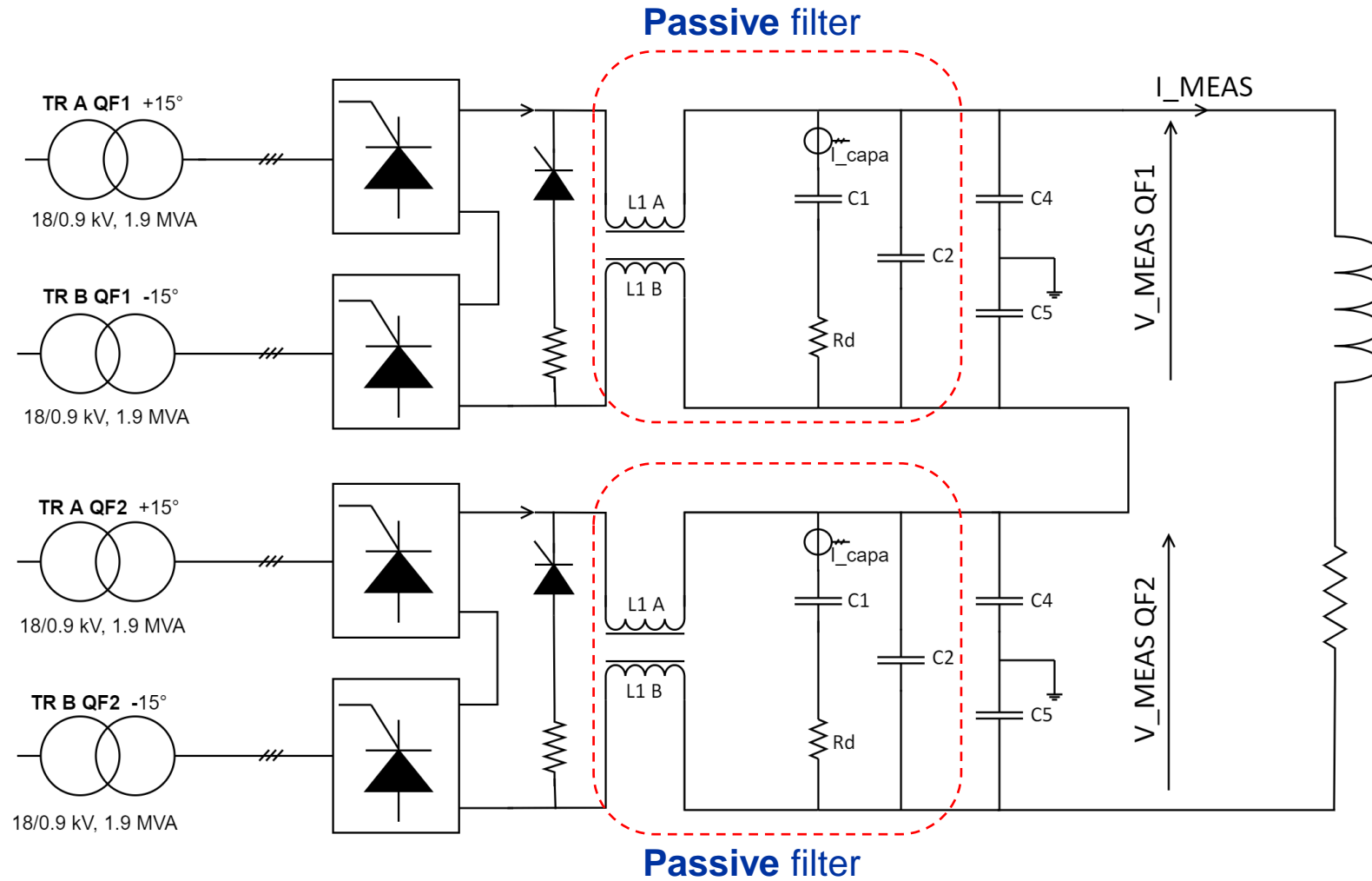
SPS main quadrupoles overview

- Ratings: 2.2 kA / 4.0 kV, < 20 ppm
- 1 SMQ station **per circuit** (QF/QD) + 1 spare
- **Digital current and voltage** regulators (FGC3)
- **Analogue firing**

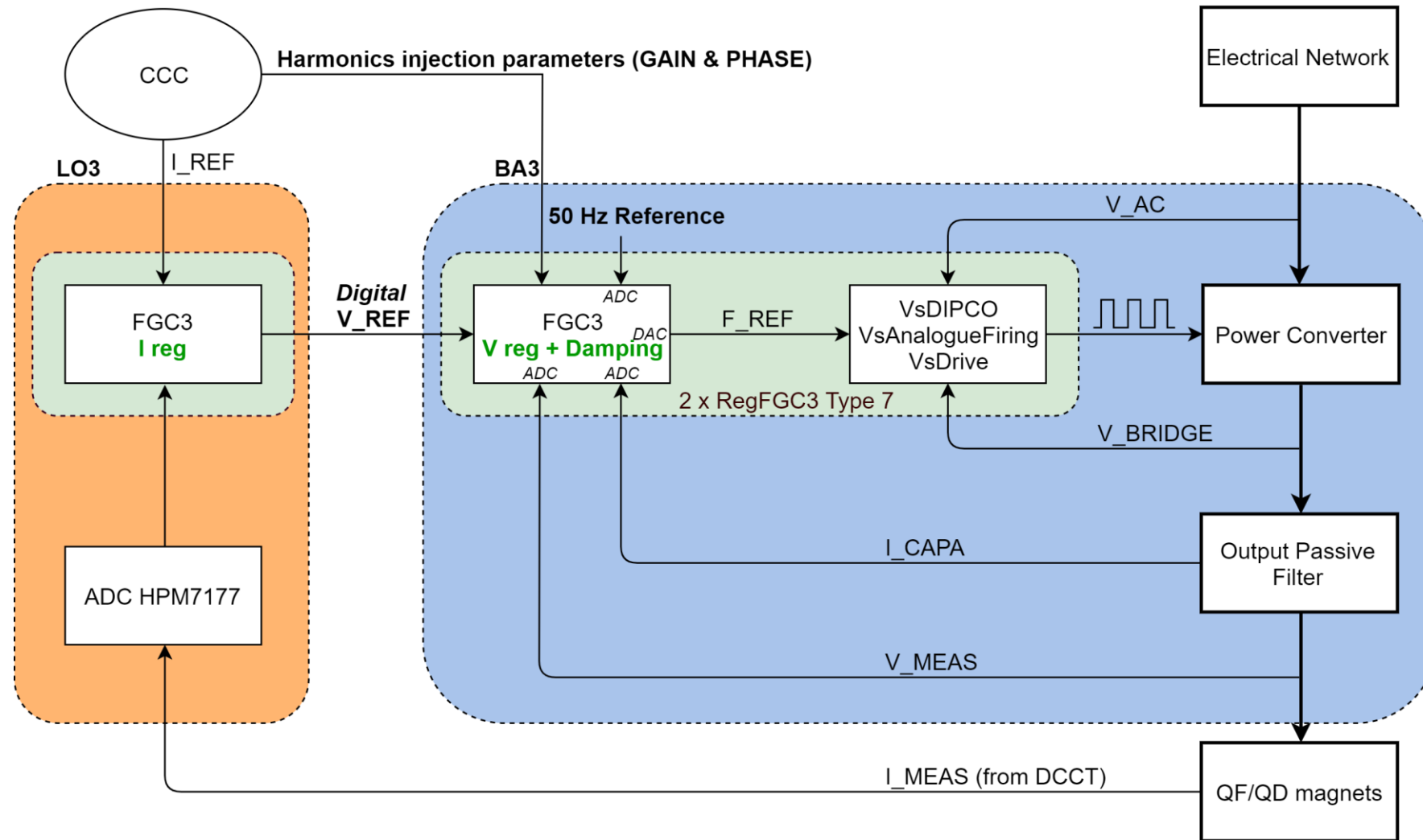


SMQ power converter layout

➤ Ratings: 2.2 kA / 3.6 kV



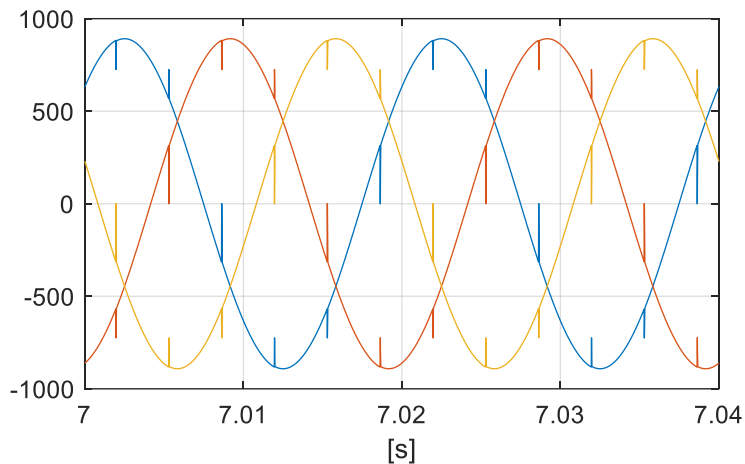
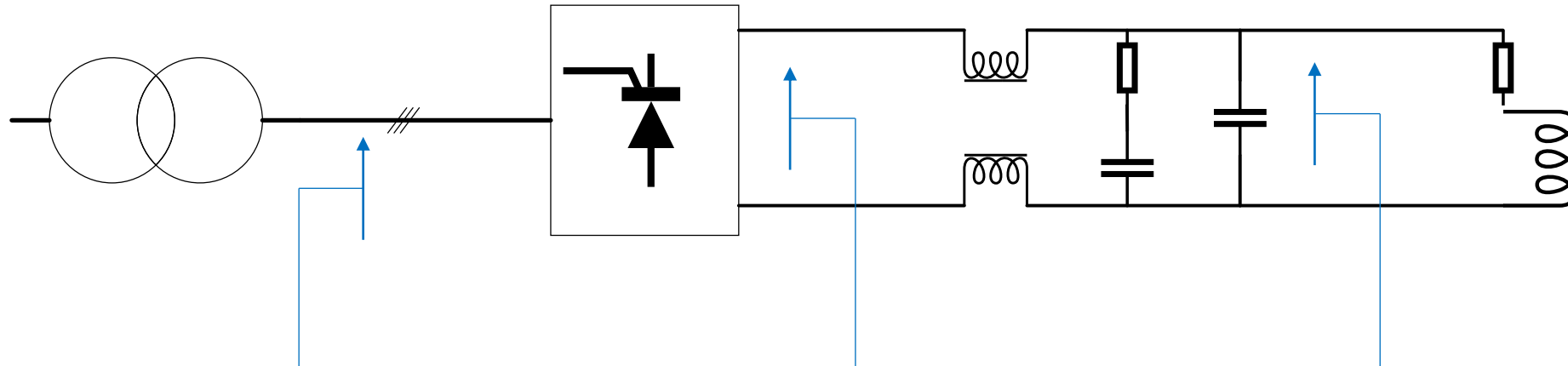
SMQ regulation structure



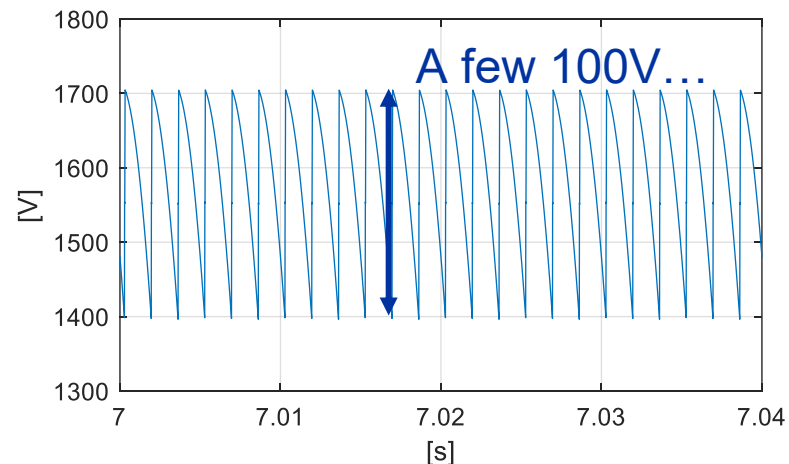
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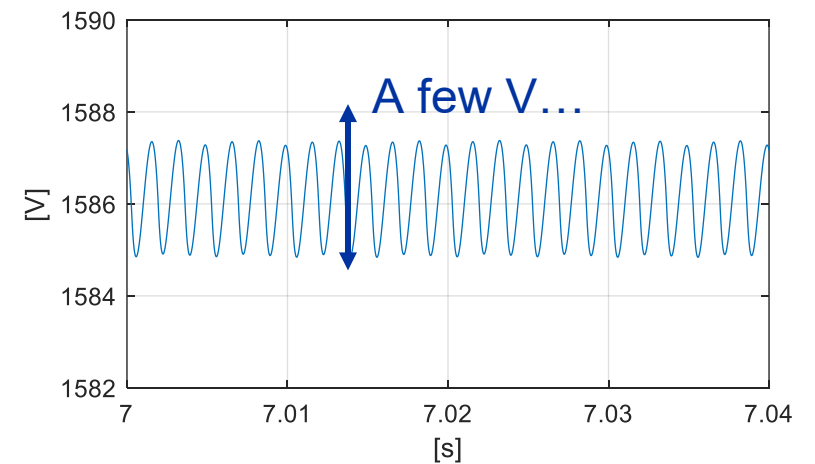
Thyristor Power Converter Noise (Part 1: Theory)



Balanced 50 Hz voltages

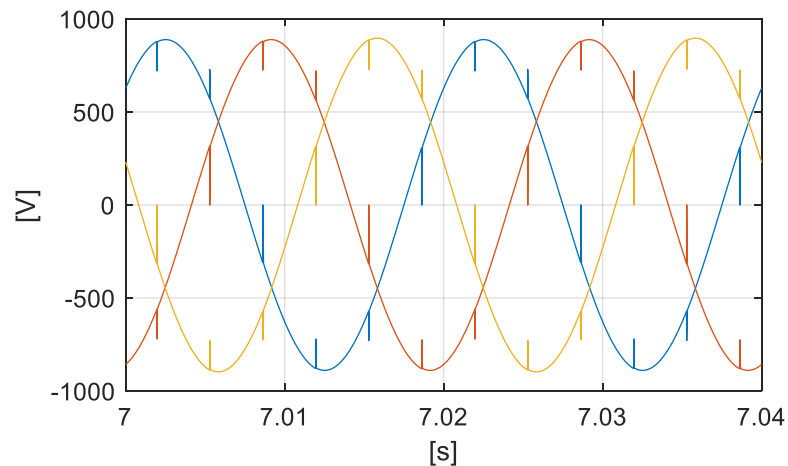
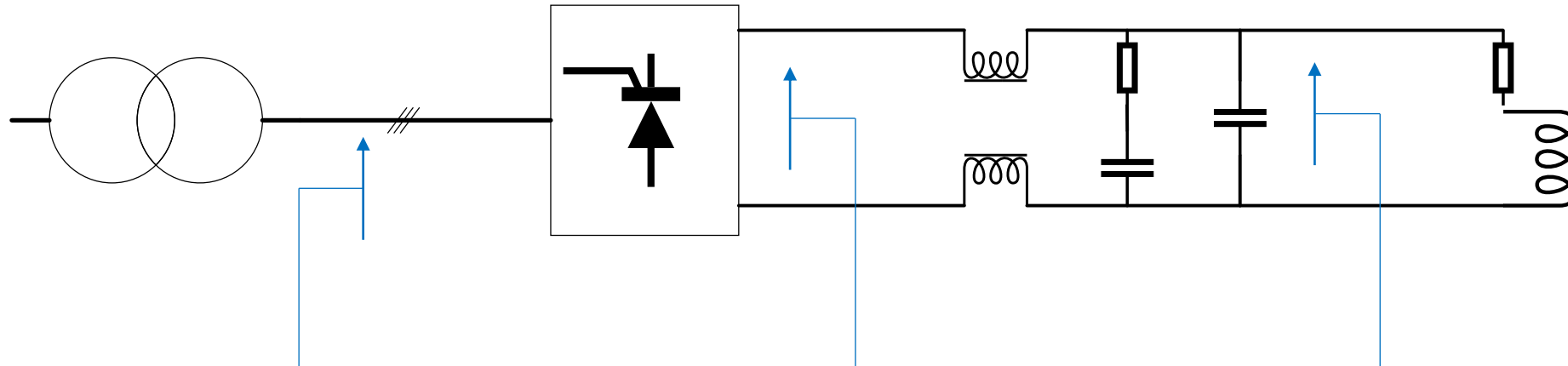


DC voltage with **large** 600 Hz

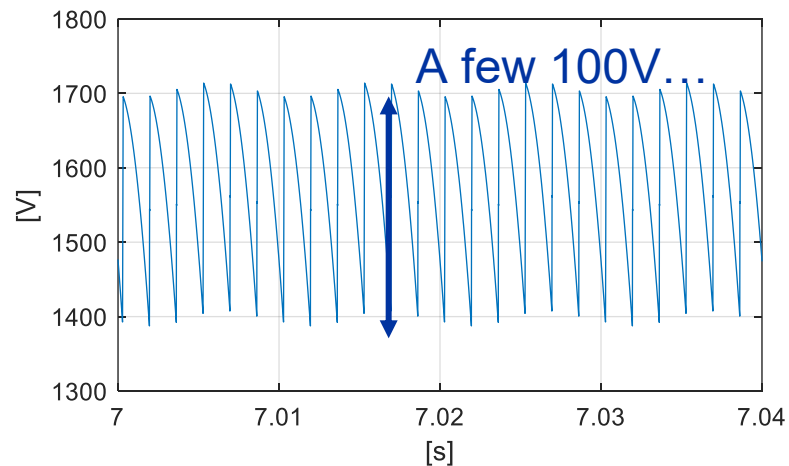


DC voltage with **low** 600 Hz

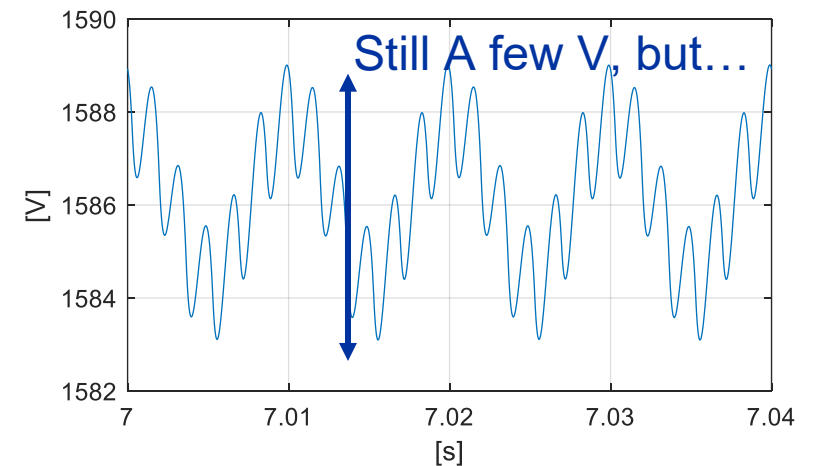
Thyristor Power Converter Noise (Part 2: Real life)



Unbalanced 50 Hz voltages
Just a few %...



DC voltage with **large** 600 Hz
+ 50 Hz, 100 Hz, 150 Hz...



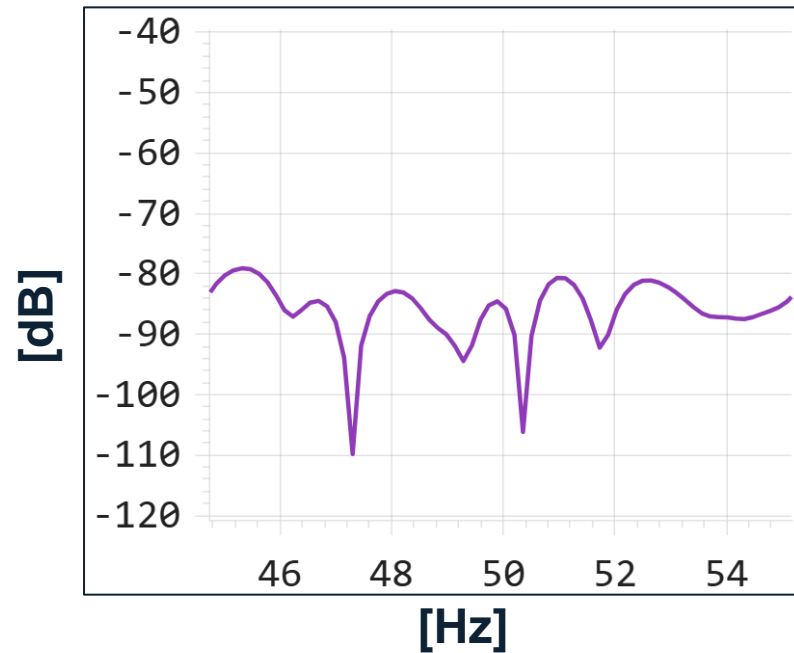
DC voltage with **low** 600 Hz
+ 50 Hz, 100 Hz, 150 Hz...

50 Hz

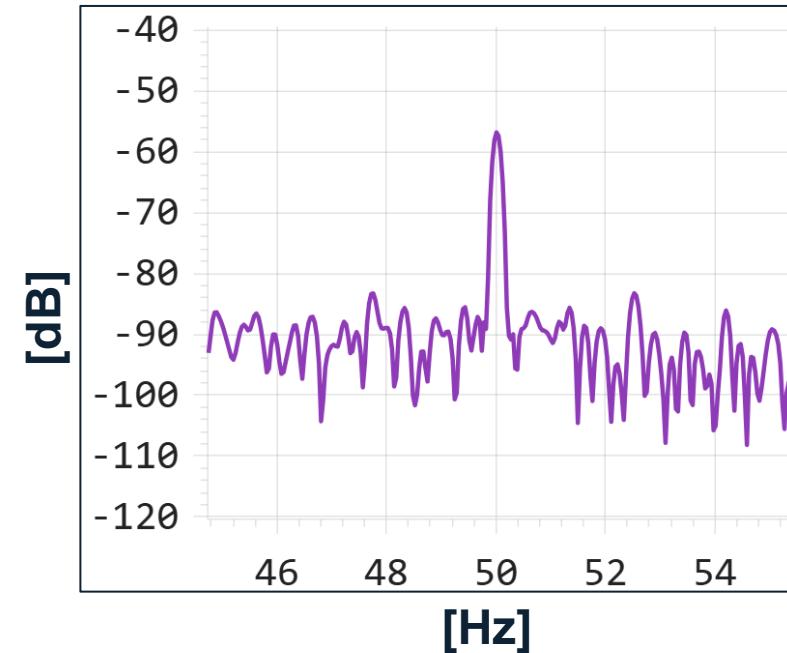
Origin of 50 Hz noise : typically comes from **couplings with power circuits**

— I MEAS QF

Converters OFF – QF circuit **open**



Converters OFF – QF circuit **closed**

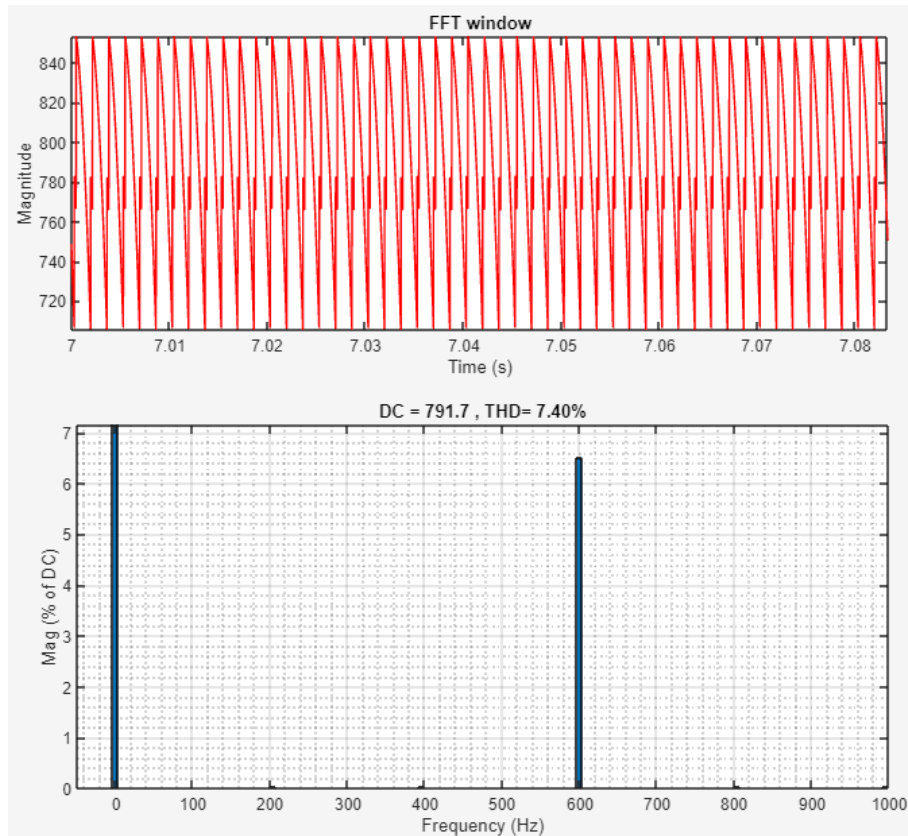


0 dB = 1.0 A RMS

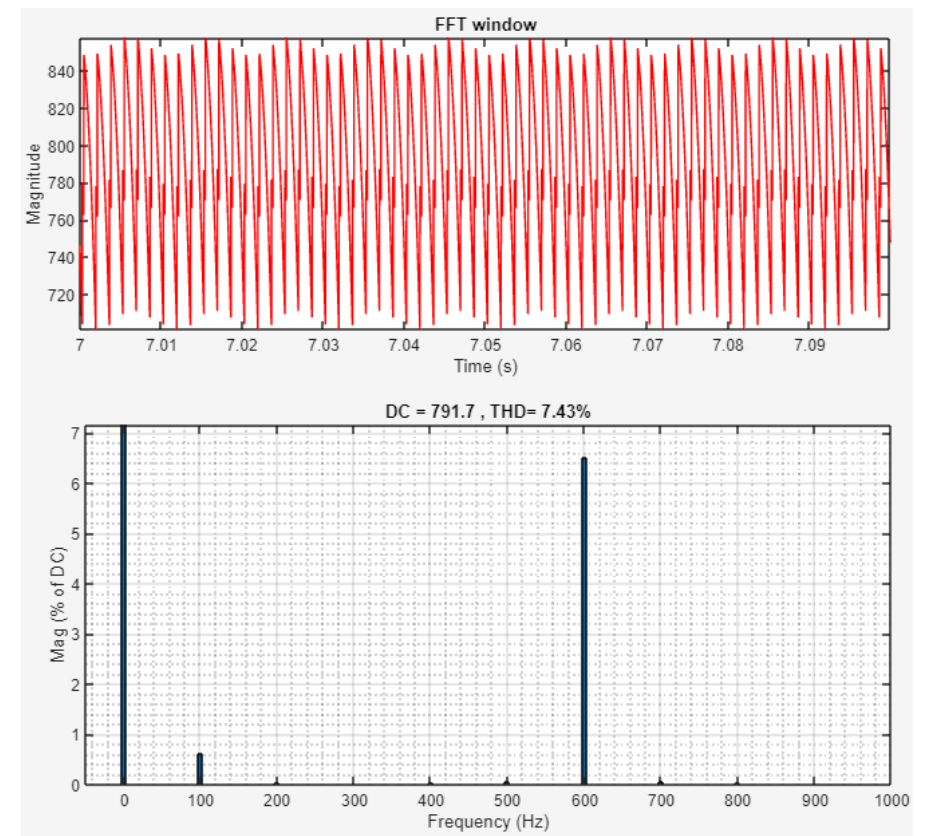
There is inherently a 50 Hz current circulating in the magnets because of couplings

100 Hz

Ideal AC network (balanced phases)



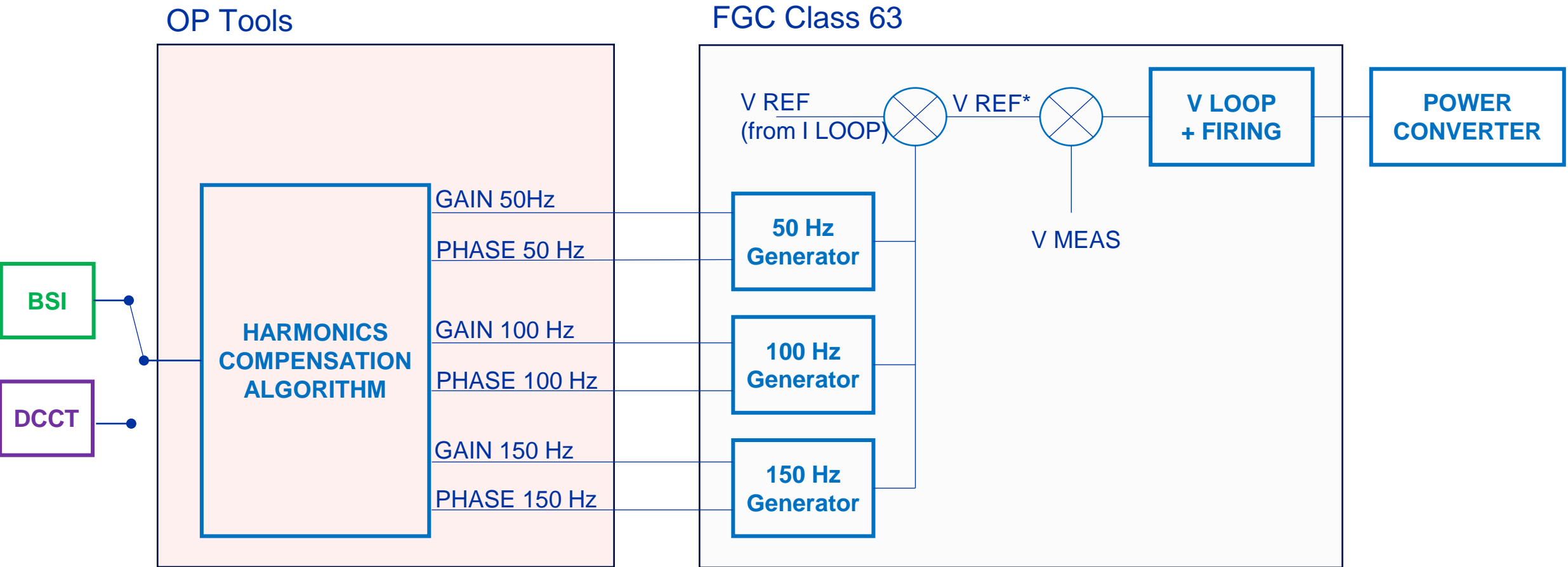
Real AC network (unbalanced phases)



100 Hz noise comes from the rectification of (naturally) unbalanced phases

How to eliminate these ripples?

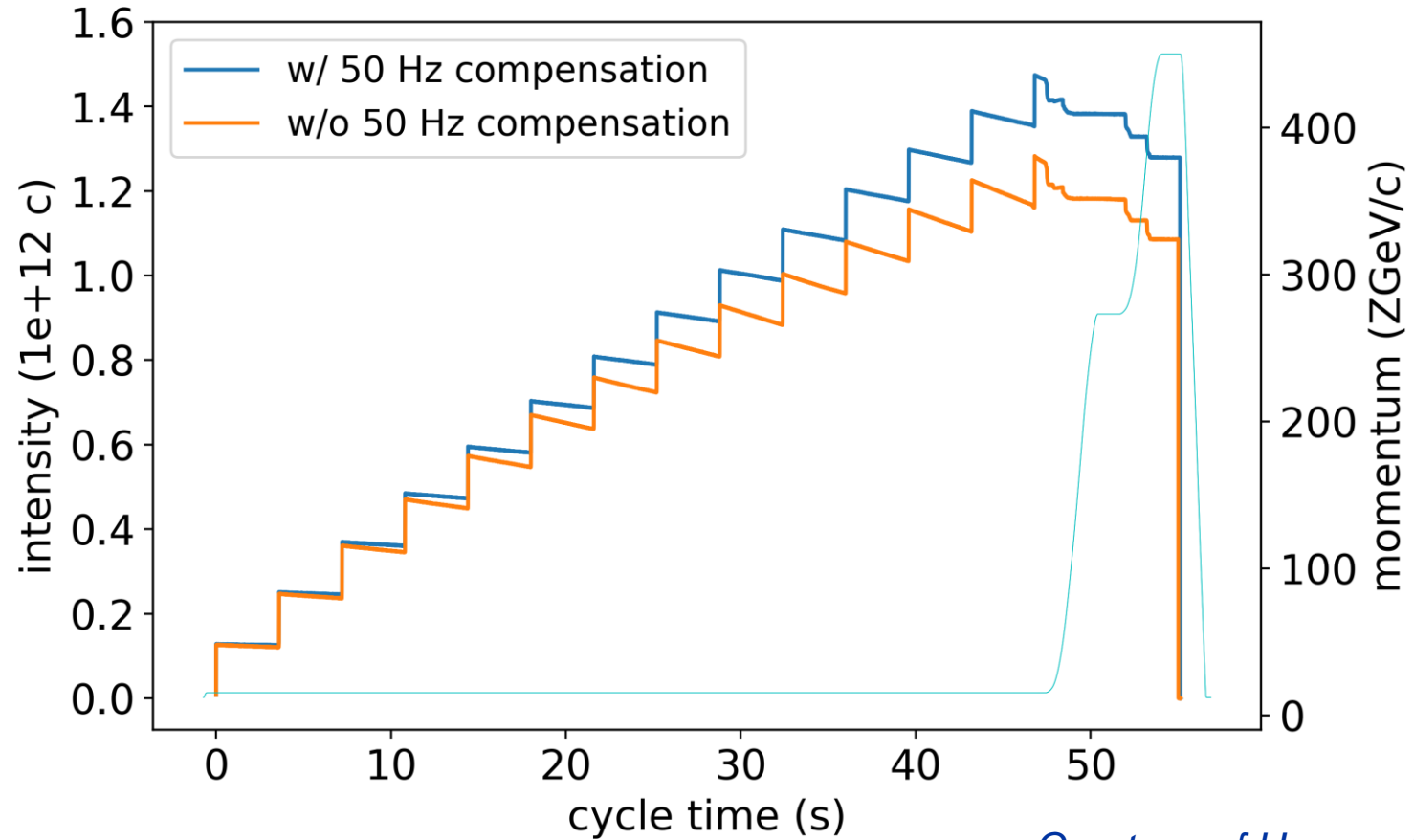
By compensating them!



Compensating BEAM noise VS. Compensating DCCT noise

Benefits of the compensation - Example

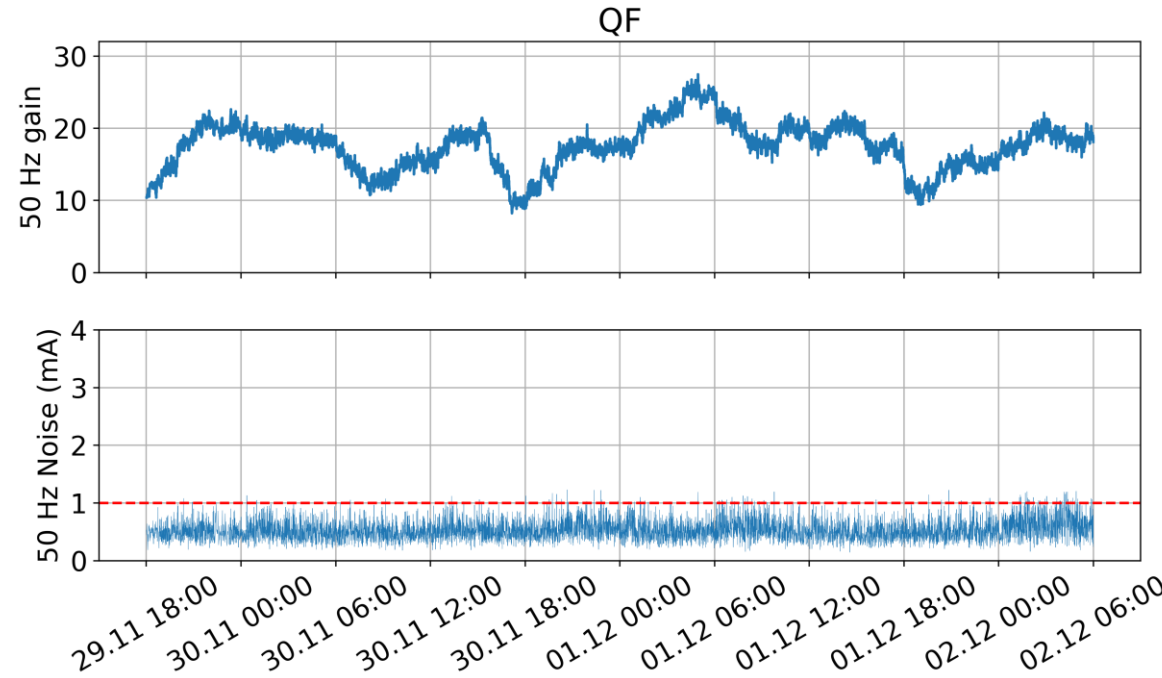
Intensity increased **by 15-20%** for LHC ion beams at injection



Courtesy of Hannes Bartosik [BE-ABP]

Confirmation in 2025

- Promising results (just before the YETS...)



Compensation
stable for > 48h !

Courtesy of Hannes Bartosik [BE-ABP]

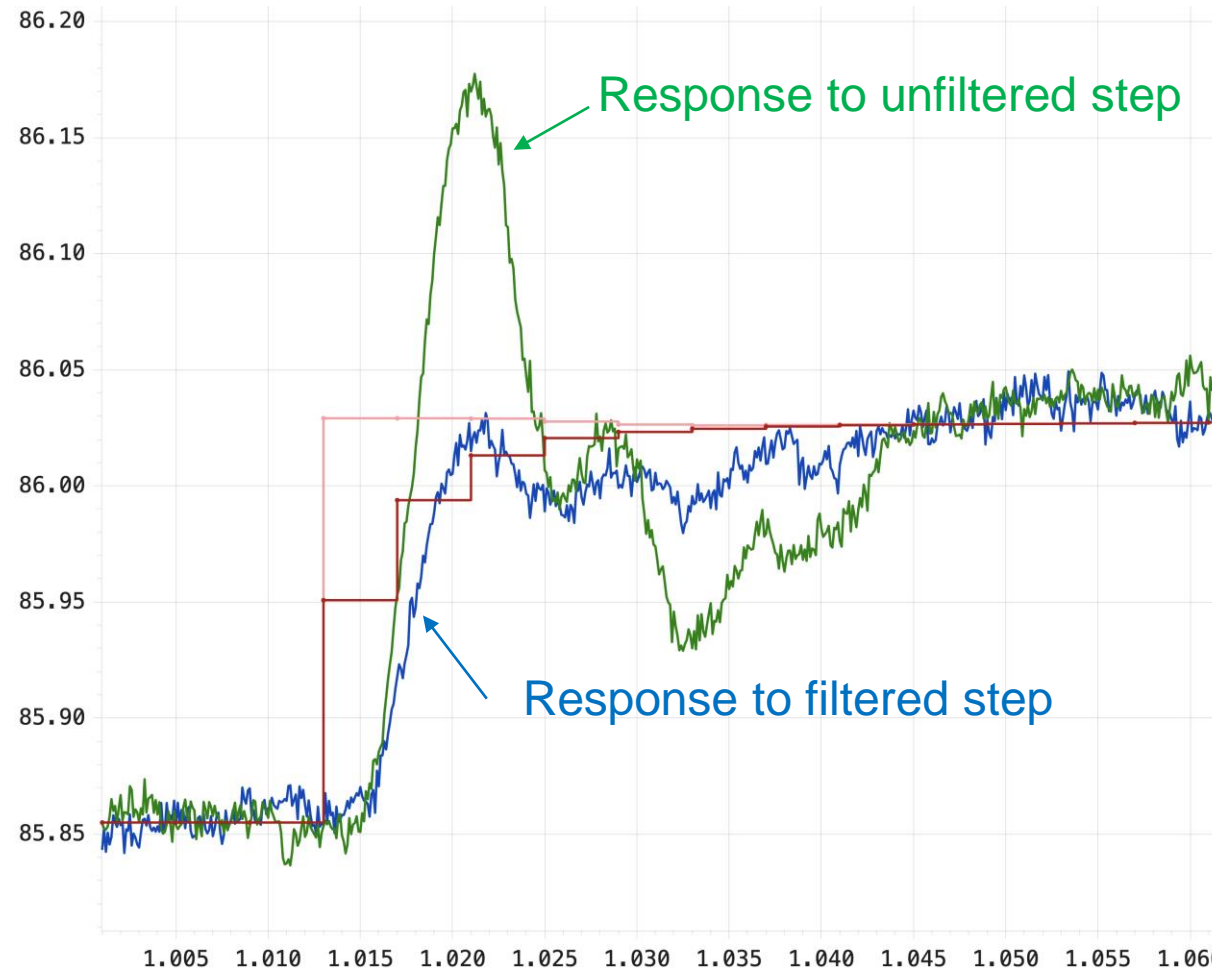
- In 2025 Compensation also available in **MBI** (See <https://indico.cern.ch/event/1447498/>)
- Questions to answer :
 - **Is it sufficient to compensate the noise on MBI, QF and QD?**
 - **Effective compensation on the beam still required?**

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Auto-tune overshoots – April 2024

Current response to a 170 mA auto-tune step (pink/green)



Issue fixed with 1st order filter on autotune step (red/blue)

Auto-tune overshoots – September 2024

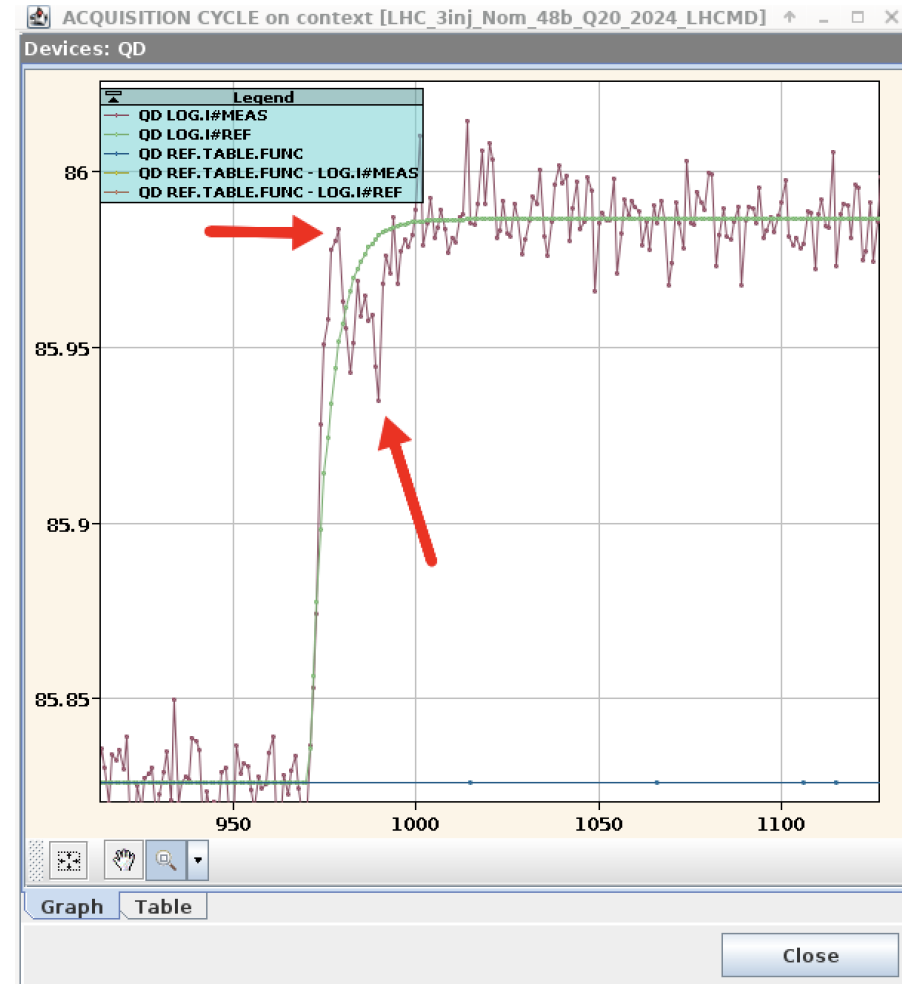
Current response to a 170 mA **filtered** auto-tune step

➤ not sufficient anymore with improved beams

Possible solutions:

- Use **more sophisticated** filtering
- **Retune** the current controller

Issue to be addressed during HWC 2025
in close cooperation with OP



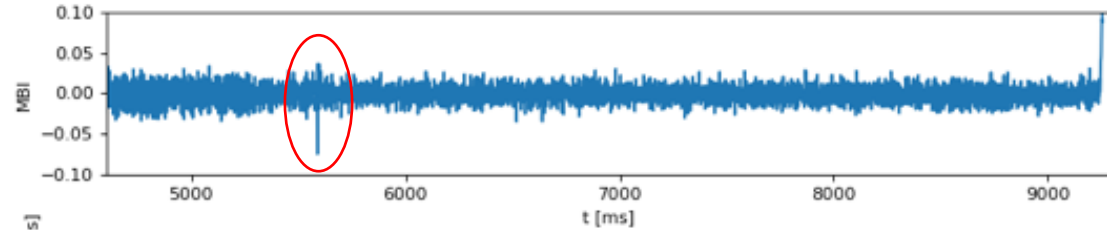
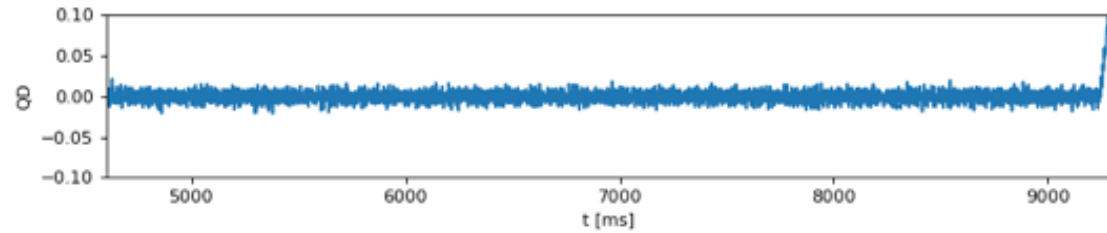
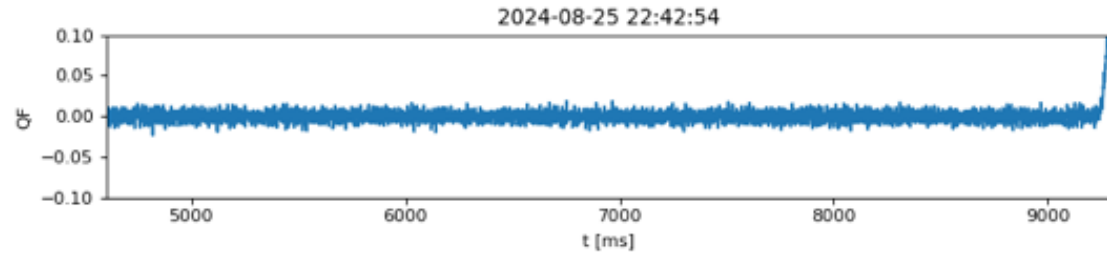
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Regulation glitches

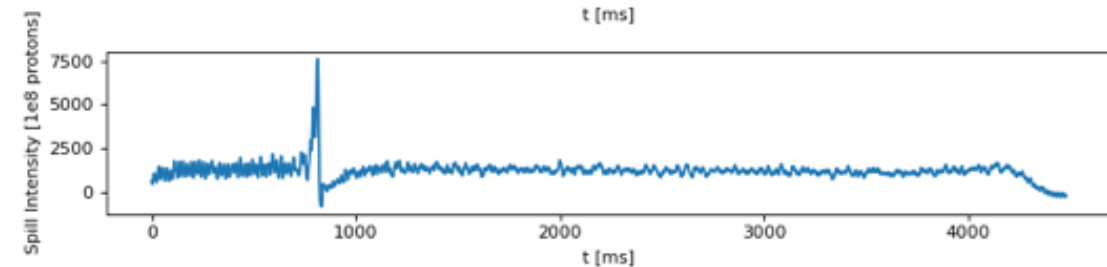
SFTPRO Flat top

Current Regulation Error



Current glitch on MBI

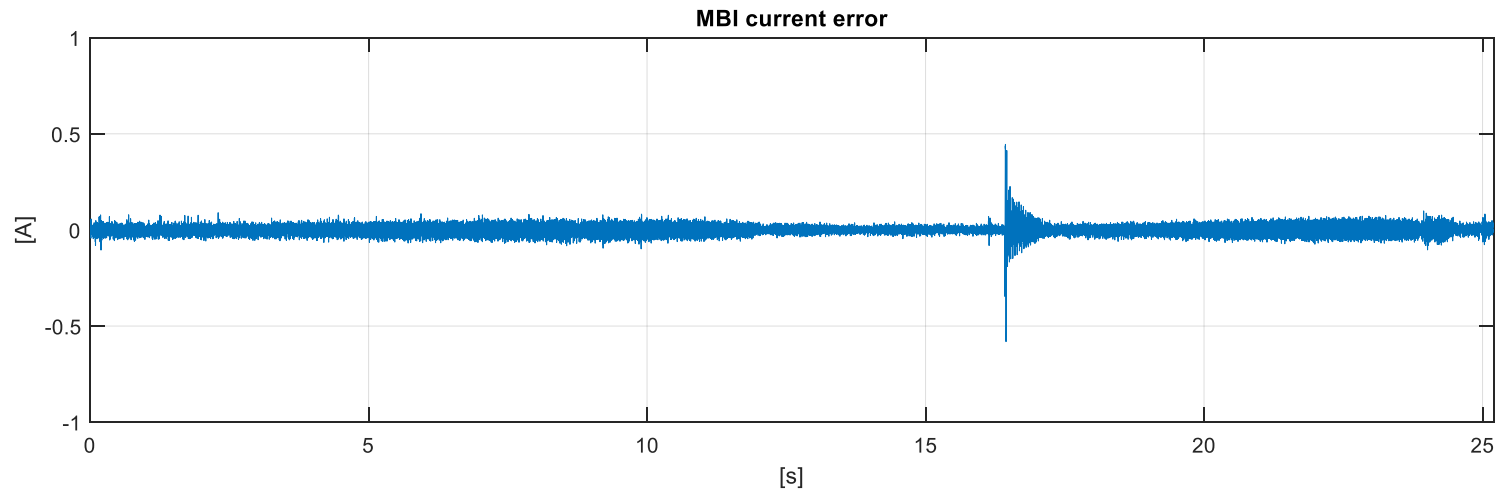
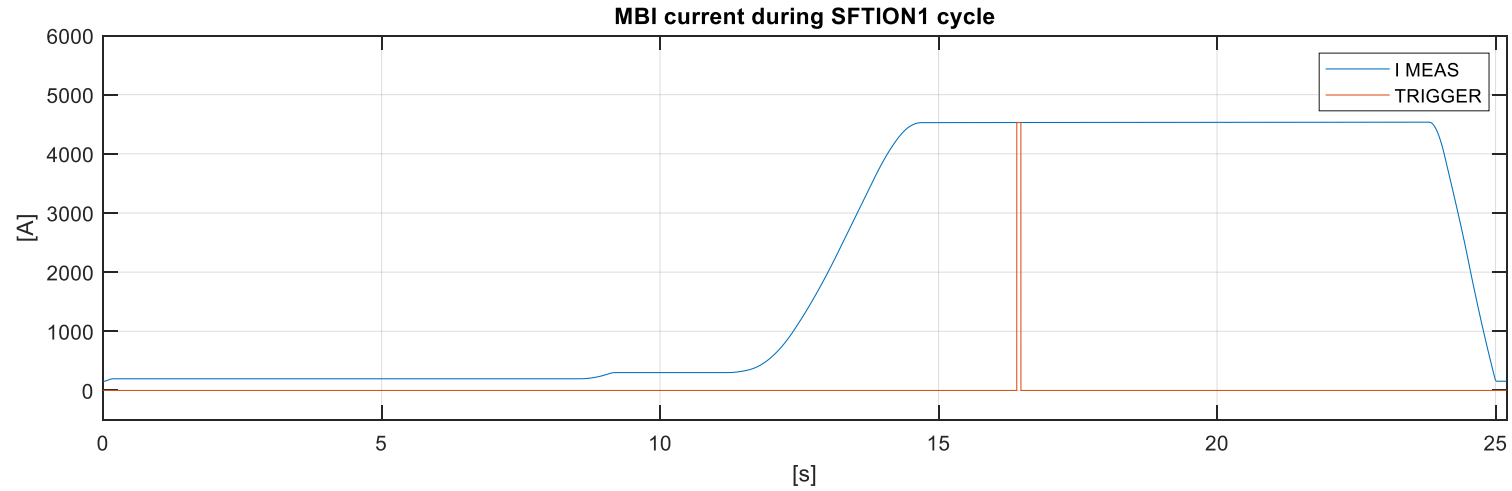
BSI



Automatic trigger of an oscilloscope not possible with such small perturbations

Glitch detector

Solution: **software glitch detector** to collect data for better diagnostic



1. Power converters ripple

- a. Enable **harmonics compensation in MBI** thanks to SMD13 consolidation
- b. Make the harmonics compensation properties **ppm**

2. Regulation overshoots

Find the best solution with OP mitigate these overshoots

→ **For re-tuning the current regulators, 5 extra half-days required**

3. Regulation glitches

Understand and fix the glitches thanks to the glitch detector

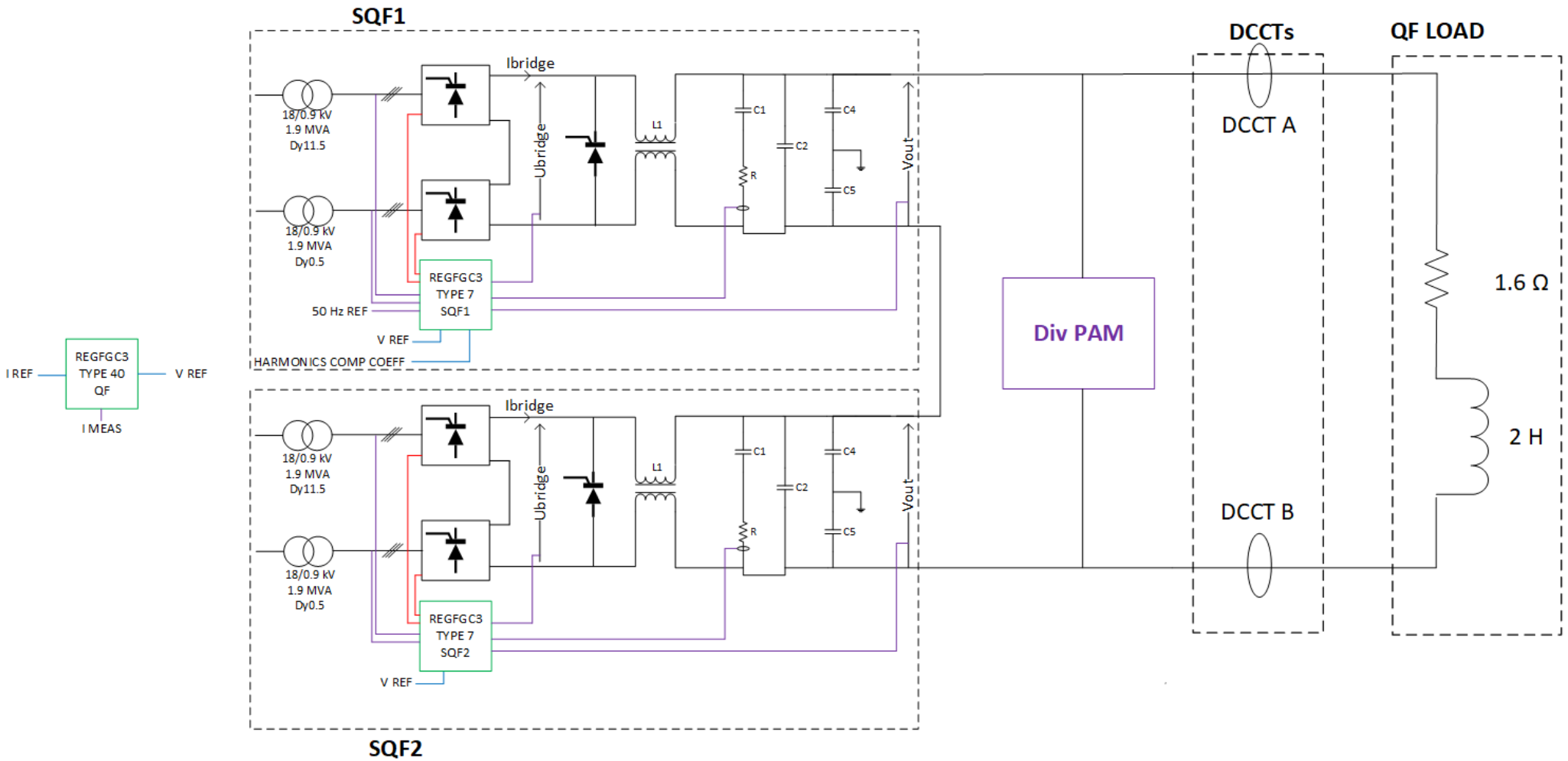
Some final words:

- Very good cooperation with the SPS team, **very interesting** challenges to tackle
- Requires a lot of resources from many persons in EPC!
- What is the **priority** of these improvements at the scale of CERN projects?

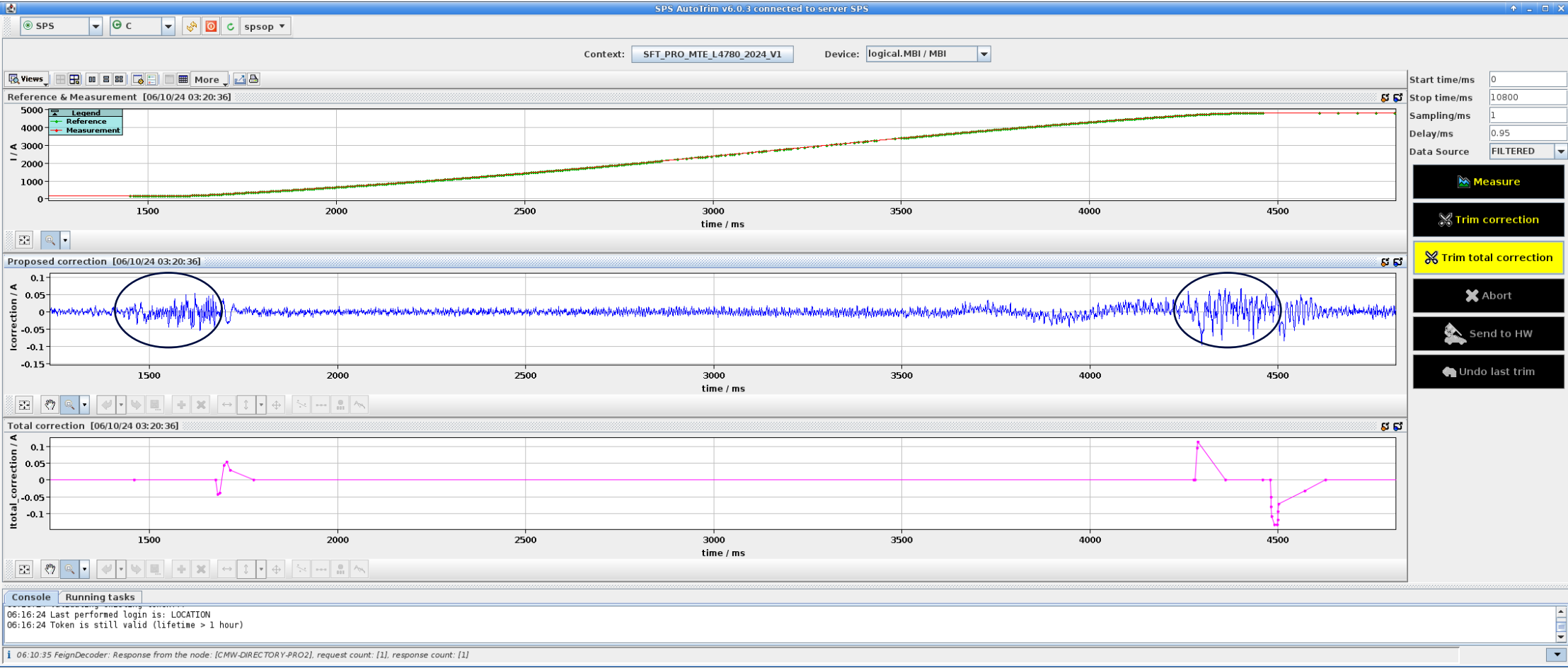


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Additional measurement in QF



Oscillations during ramp-up



Oscillations during ramp-up – 2023 vs. 2024

