Effect of flux jumps on main field and field quality of MBH magnets

Lucio Fiscarelli

CERN, 26/02/2019

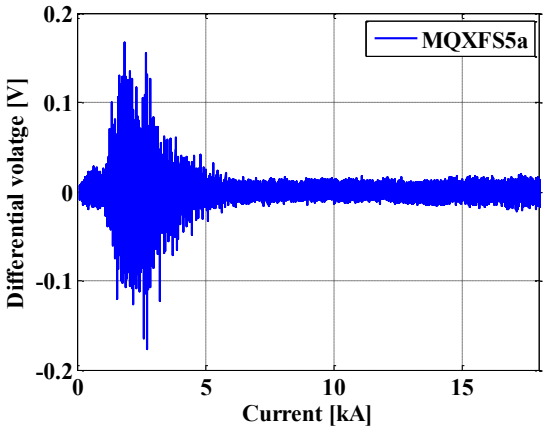
Outlook

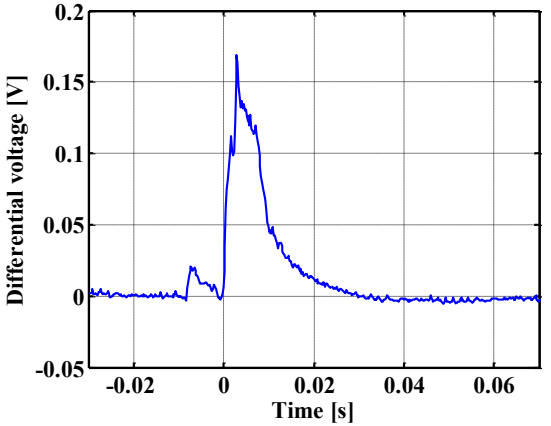
- Experimental observations of flux jumps
- How to measure their effect on the field
- Case of MBHSP9 (11 T short model)
  - Flux measurements
  - Current measurements
  - Study of the effect from the current control
  - Spectra
- Conclusions

Flux jumps

Experimental observations

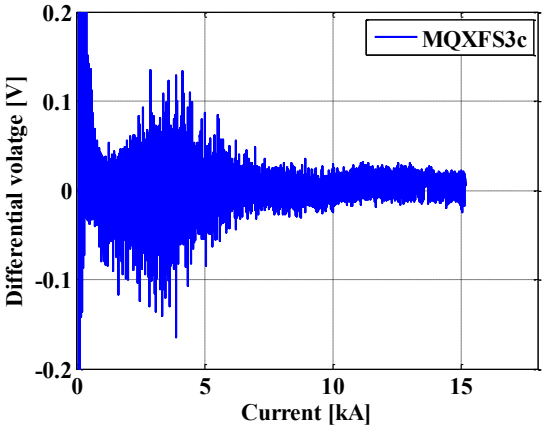
- Spikes on the voltage measured across the magnet leads or at the terminals of a single magnet coil
- Bucked signals - difference of signals from two or more coils - show them more clearly
- Specific signature different from mechanical vibrations or from power-converter ripple

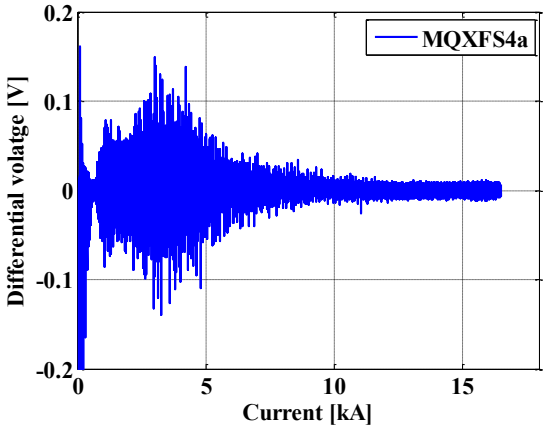


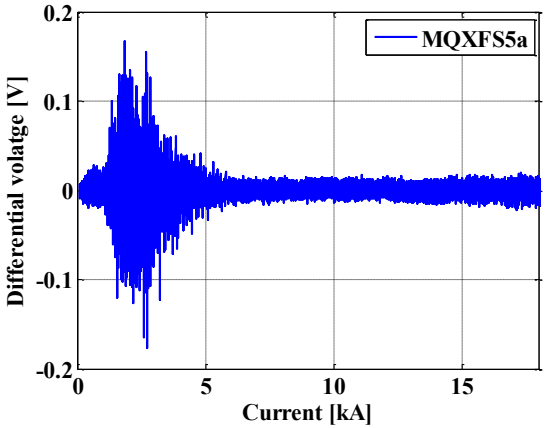


Flux jumps on differential voltage

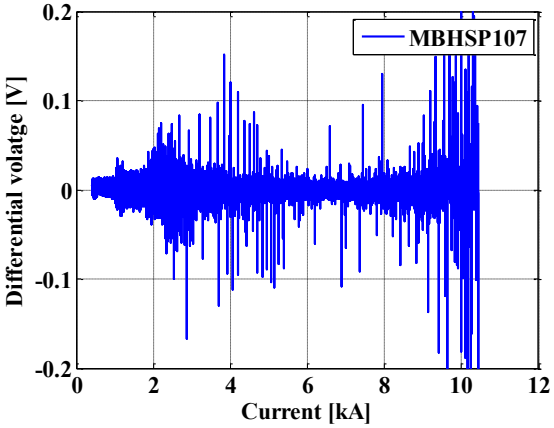
MQXFS (1.5 m)

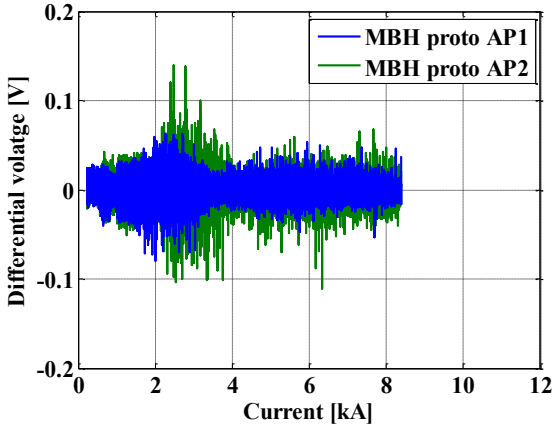






MBH 11 T (1.8 m and 5 m)





Similar behavior on Nb_3Sn magnets tested at CERN to date

- Amplitude <150 mV
- Mainly at low or intermediate field
- From these data we see same amplitude on MBH full-length proto

* Data provided by E. De Matteis TE-MPE-EP

Effect of flux jumps on the magnetic field

Flux jumps

- are “fast” events (bandwidth ~100 Hz)
- occur during ramps
- mainly at low or intermediate field levels (2 - 4 T)

How can we evaluate their effect on the magnetic field?

1) Fixed pickup coils

- bandwidth ~1 kHz
- only the change of field
  - main field
  - up-down gradient as difference of two different coils in opposite position (field quality)
- very precise (~10^{-5}) on short time intervals (<10 s)

2) Precise measurement of the current

- changes of the current will have a proportional effect on the field

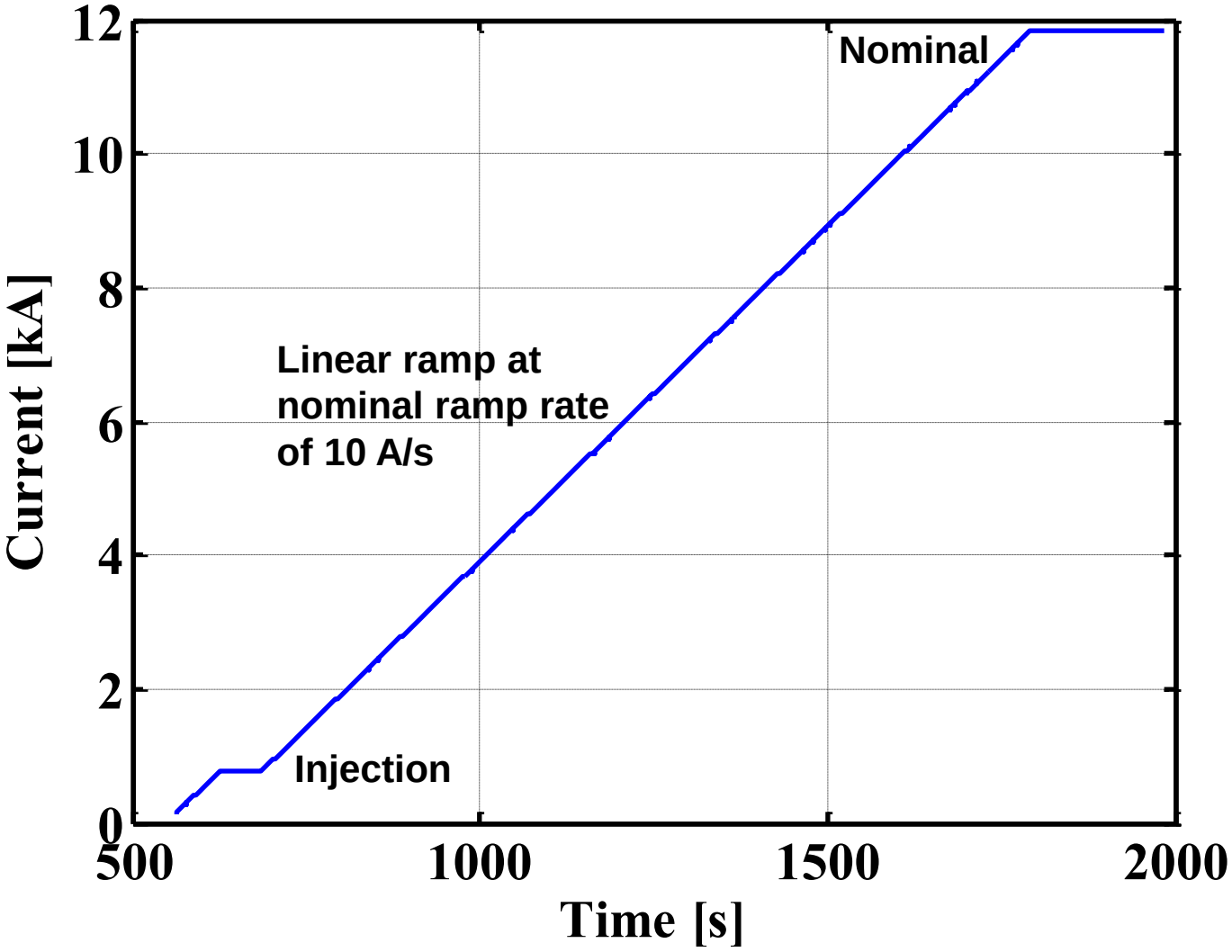
Case of MBHSP109

We have performed a test campaign dedicated to flux jumps

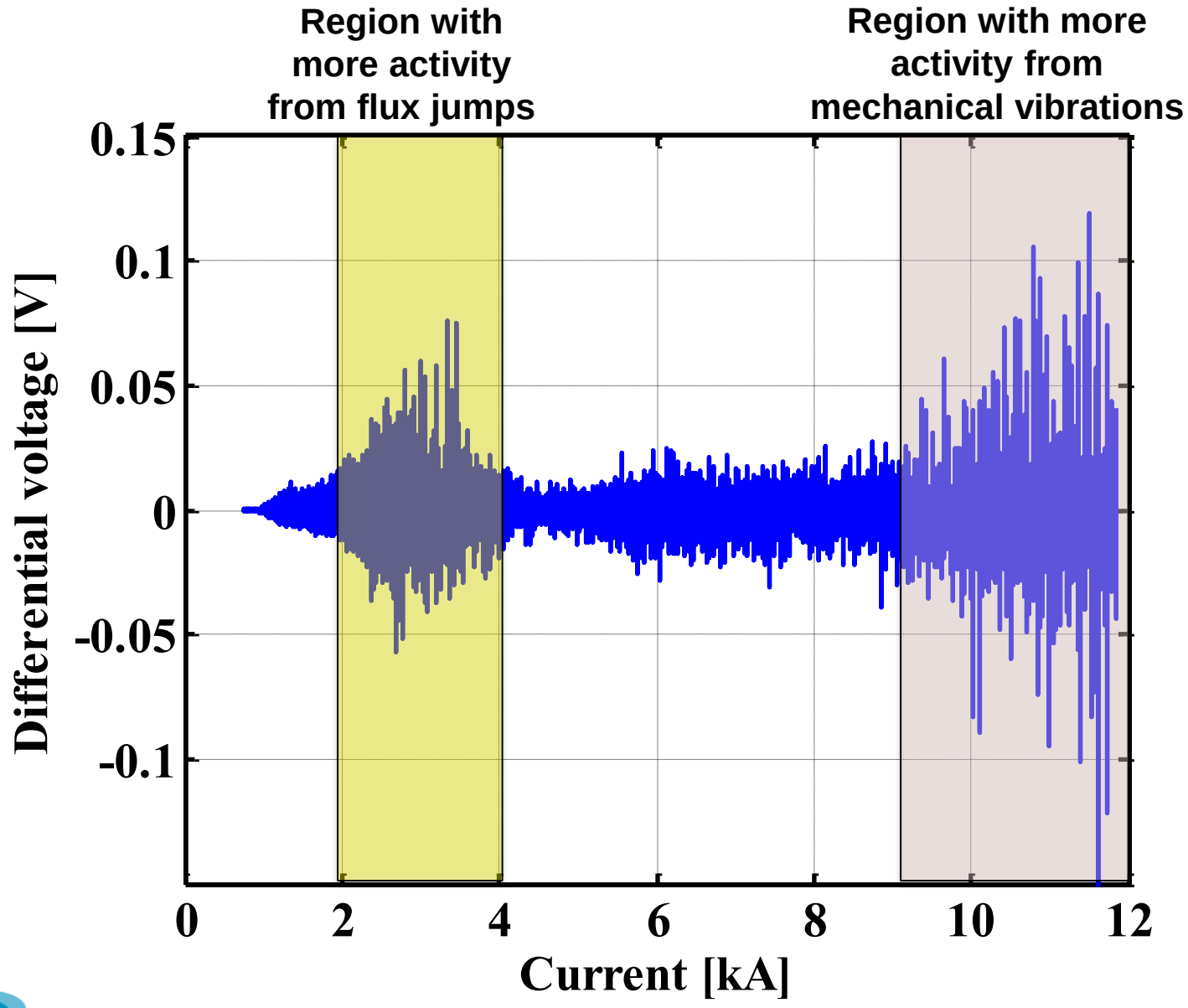
- Powering cycle
  - Pre-cycle up to nominal and 5 minutes plateau
  - Reset current at 100 A
  - Ramp at nominal ramp rate (10 A/s) from injection to nominal field level

- Acquisition
  - Integrators triggered at 5 kHz
    - Flux from fixed coils perpendicular to the field
    - Differential voltage from the two magnet coils
  - Current
    - Reading from the FGC gateway at 50 Hz
    - Synchronized to the flux via timestamp

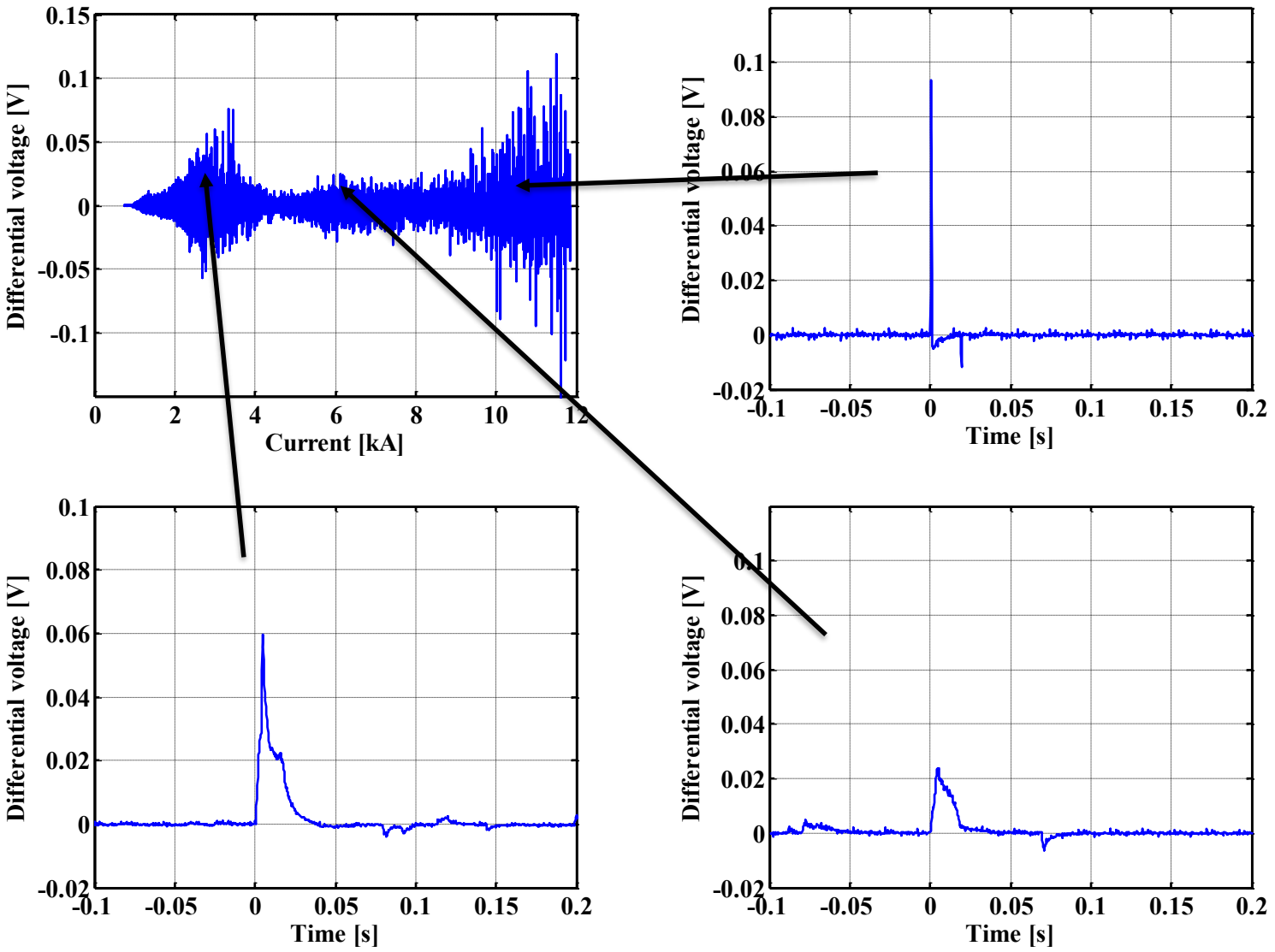
MBHSP109 – Powering cycle



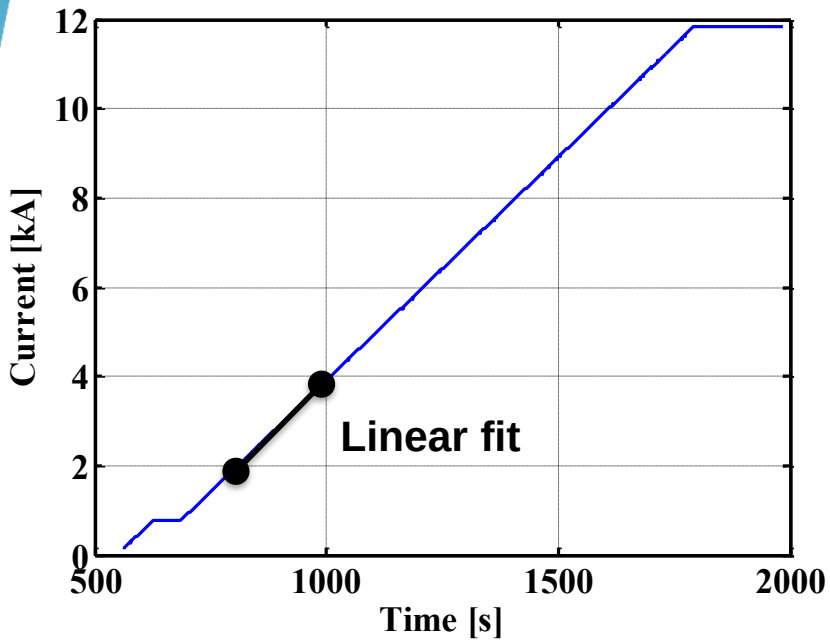
MBHSP109 - Differential voltage

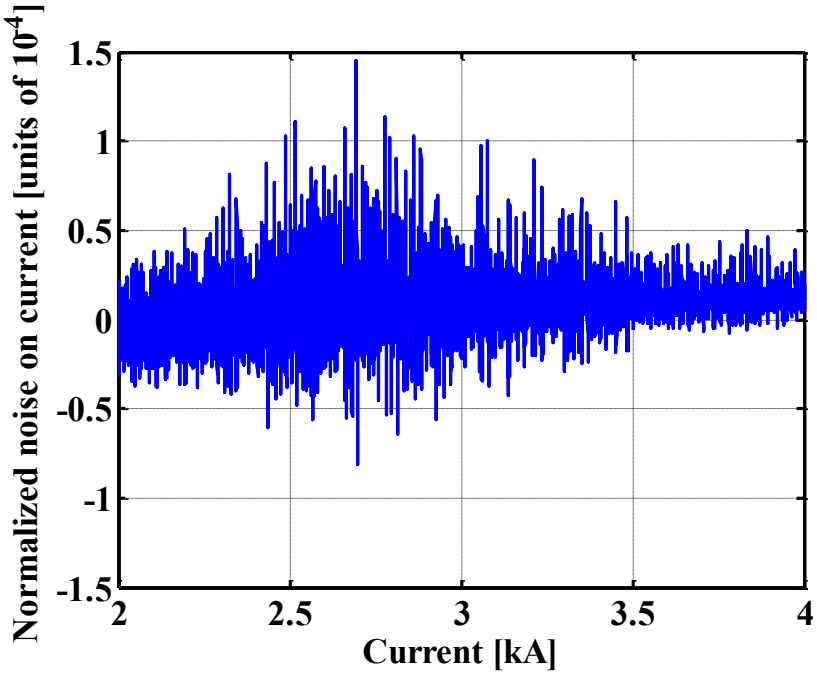


MBHSP109 - Differential voltage



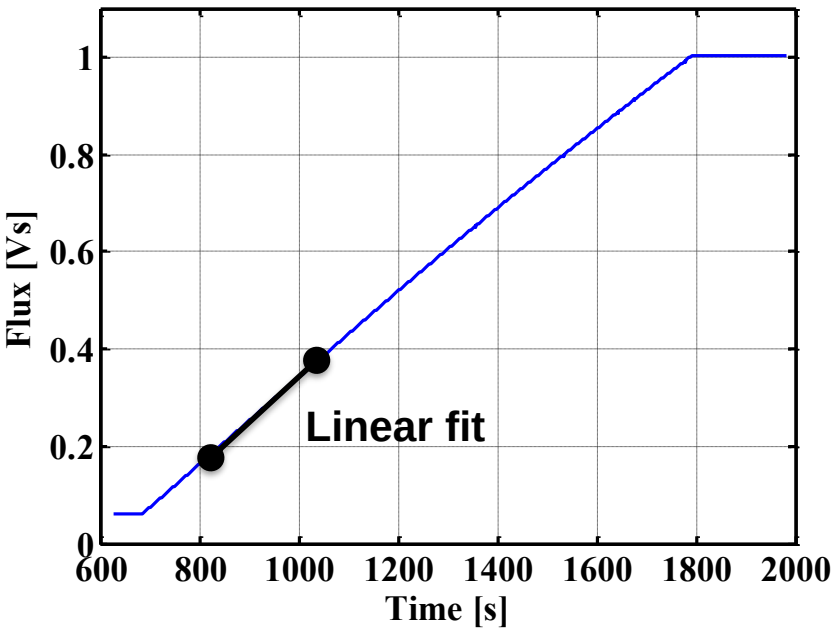
MBHSP109 - Current

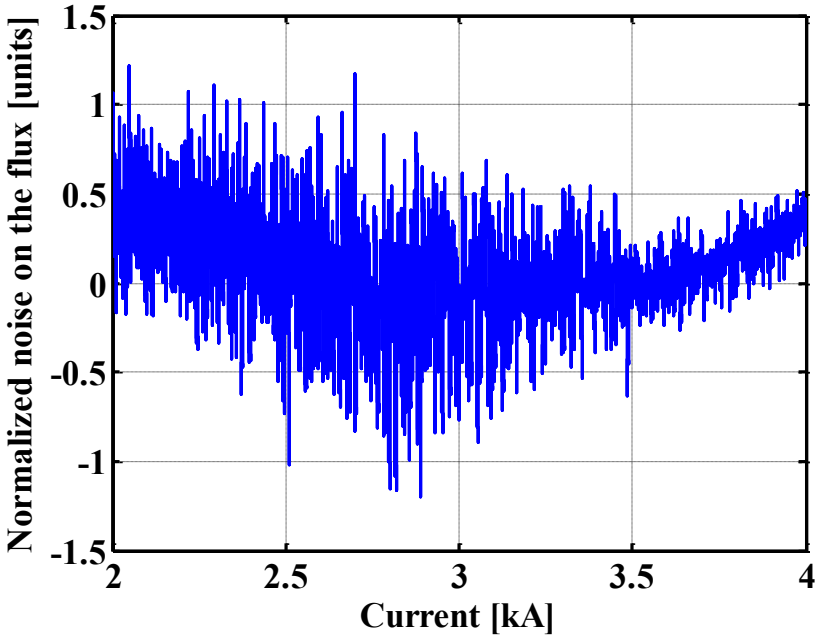




We analyze the residuals from a linear fit:
we see a "noise" on the measured current with
relative amplitude up to $1*10^{-4}$

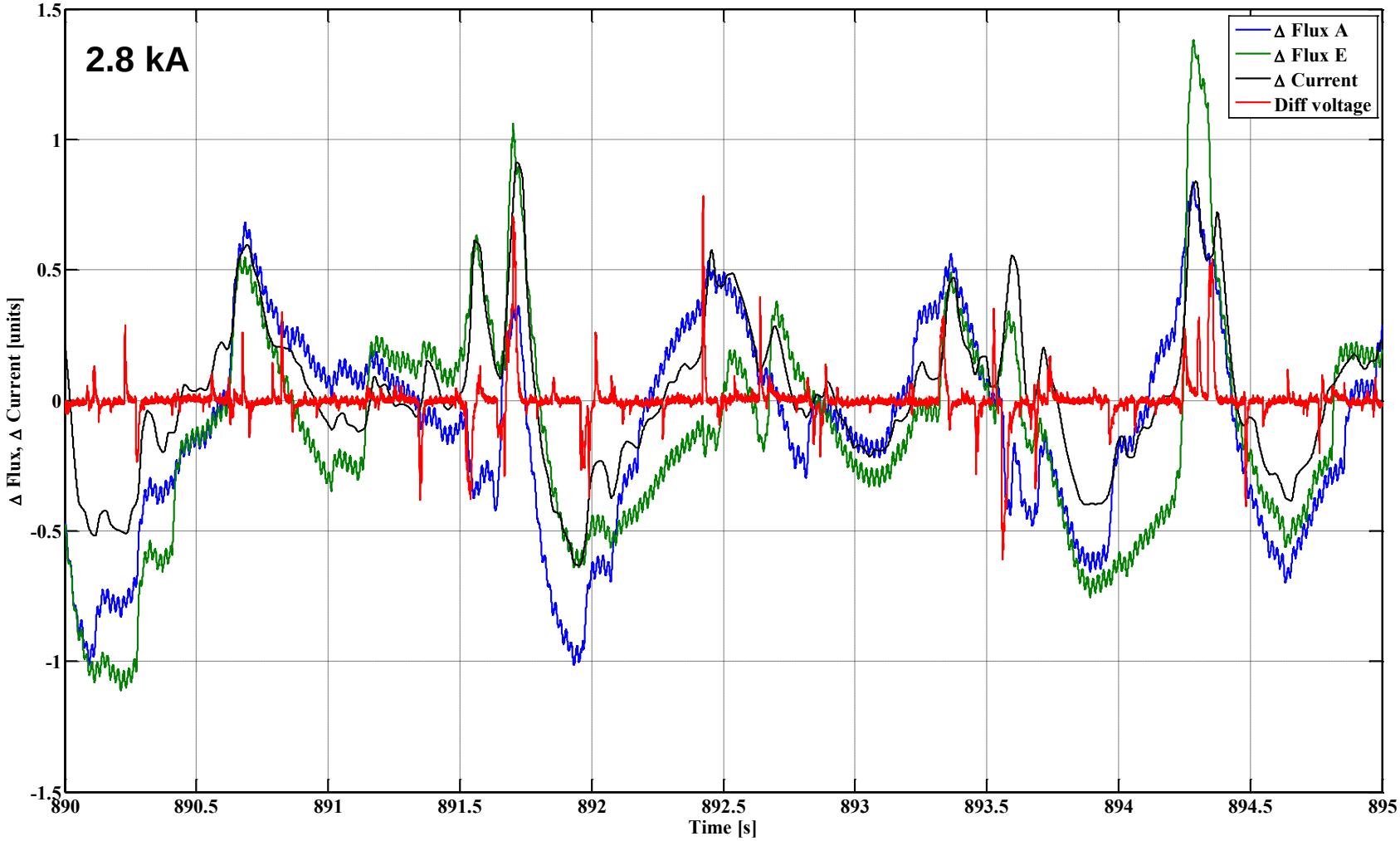
MBHSP109 - Flux





We analyze the residuals from a linear fit: we see a "noise" on the measured flux with relative amplitude up to $1*10^{-4}$

MBHSP109 - Residuals and differential voltage

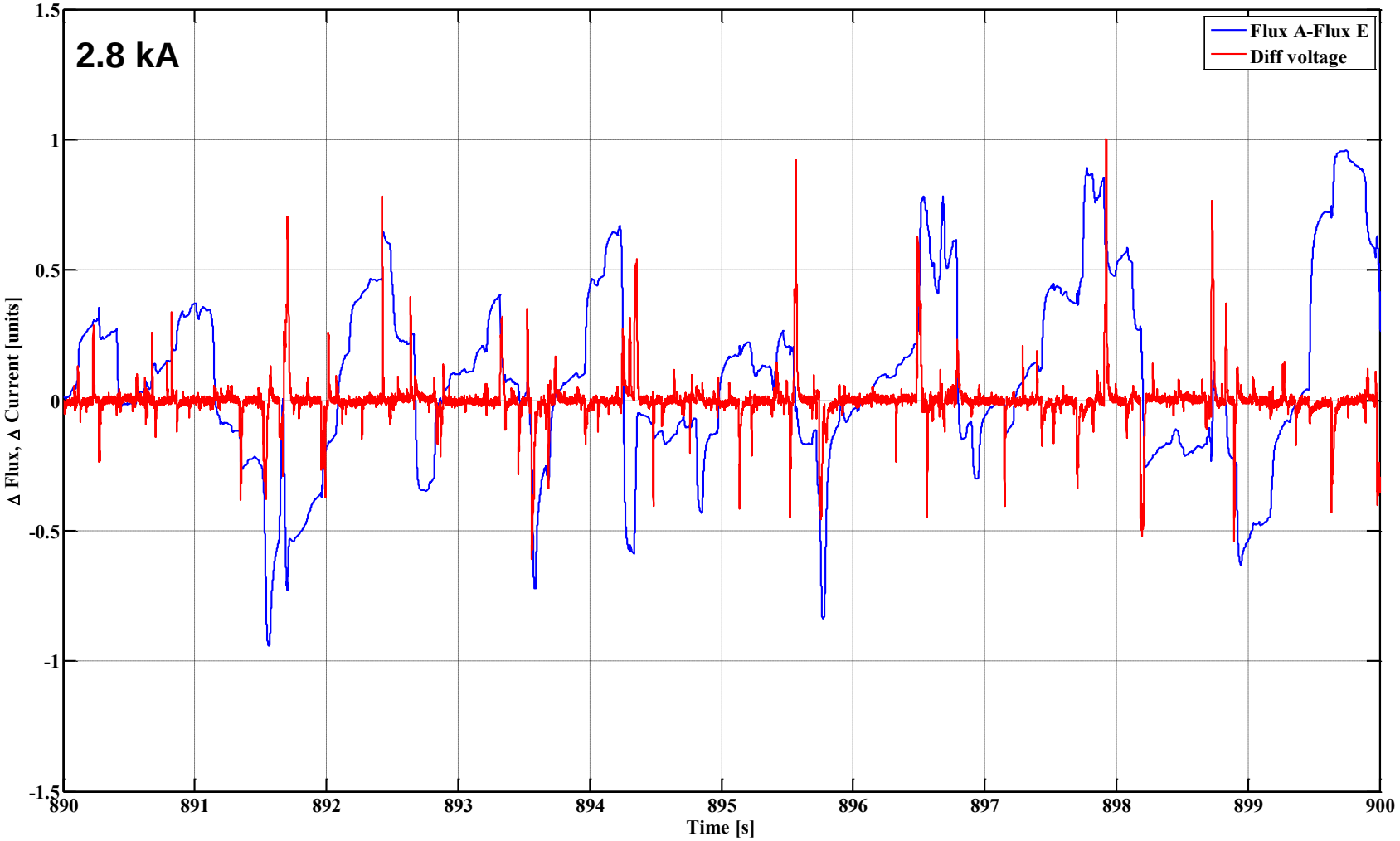


Current and flux show peaks related to voltage spikes (±1 unit).

Flux and current are not in perfect agreement after a spike (~±0.5 units).

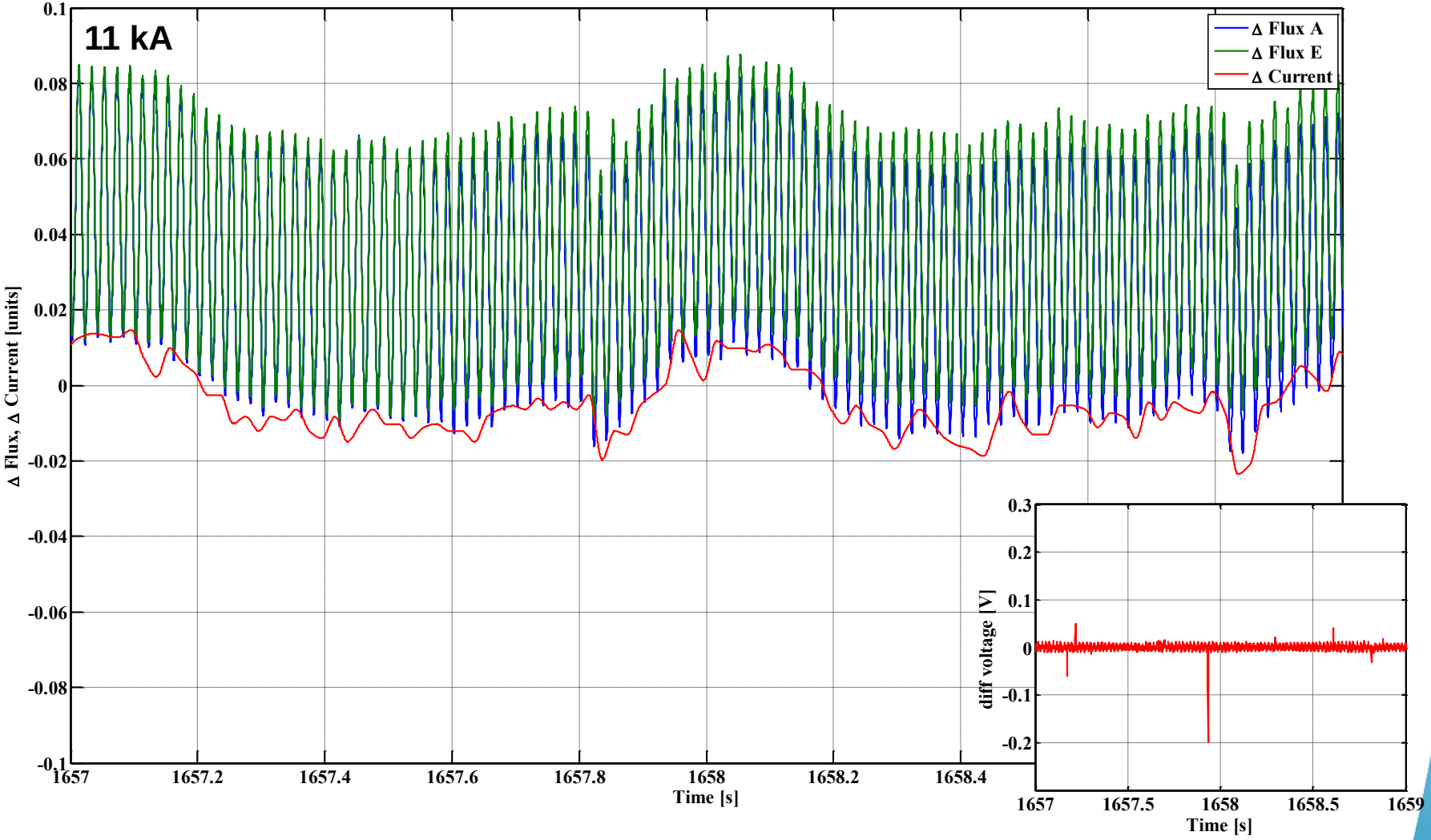
Fluxes from opposite pickup coils are not in perfect agreement (gradient).

MBHSP109 – Gradient and differential voltage



The gradient (~field quality) shows changes in the order of ±0.5 units.

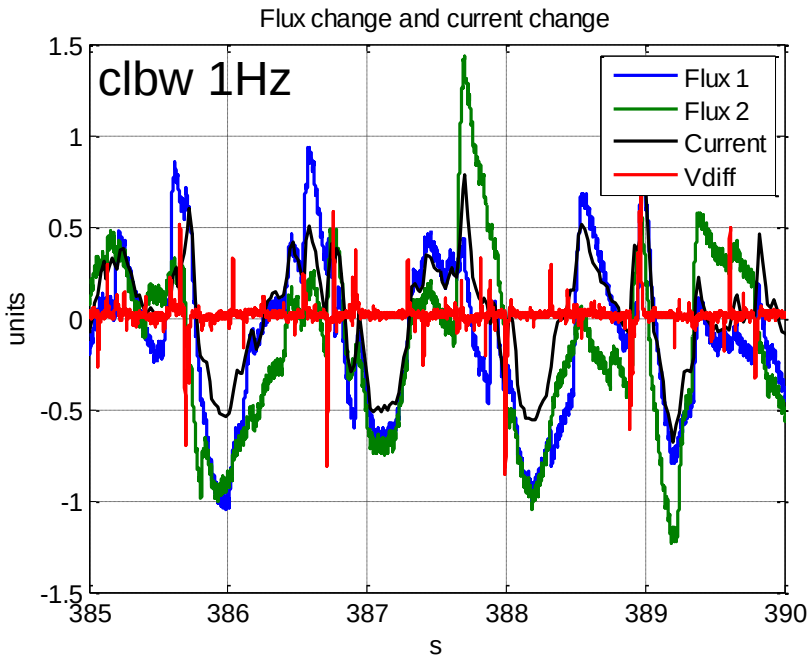
MBHSP109 - Residuals and differential voltage

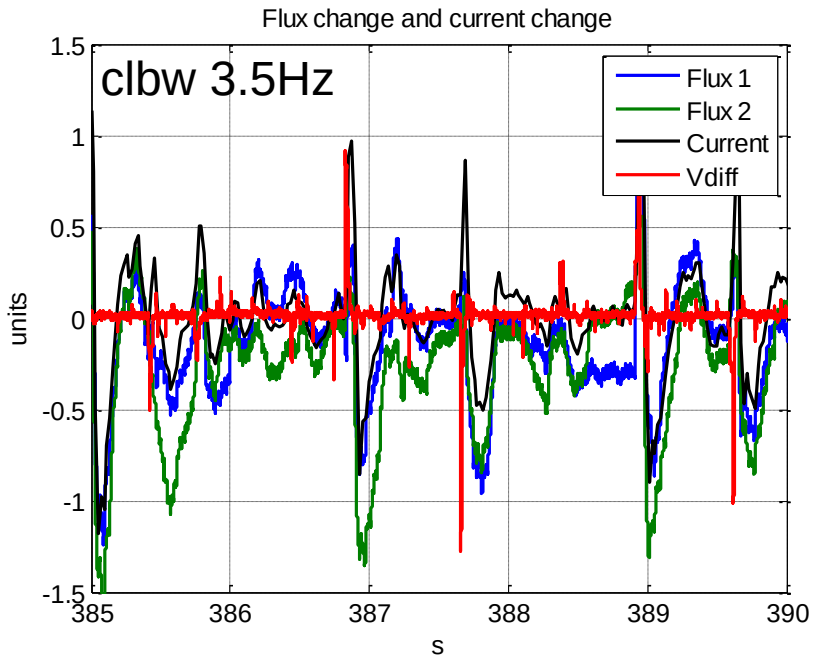


At higher field we see a perfect agreement (<10^{-6}) of fluxes and current.

***On the flux we see the noise at 50 Hz that is filtered on the current.**

MBHSP109
Study of the effect of the current control

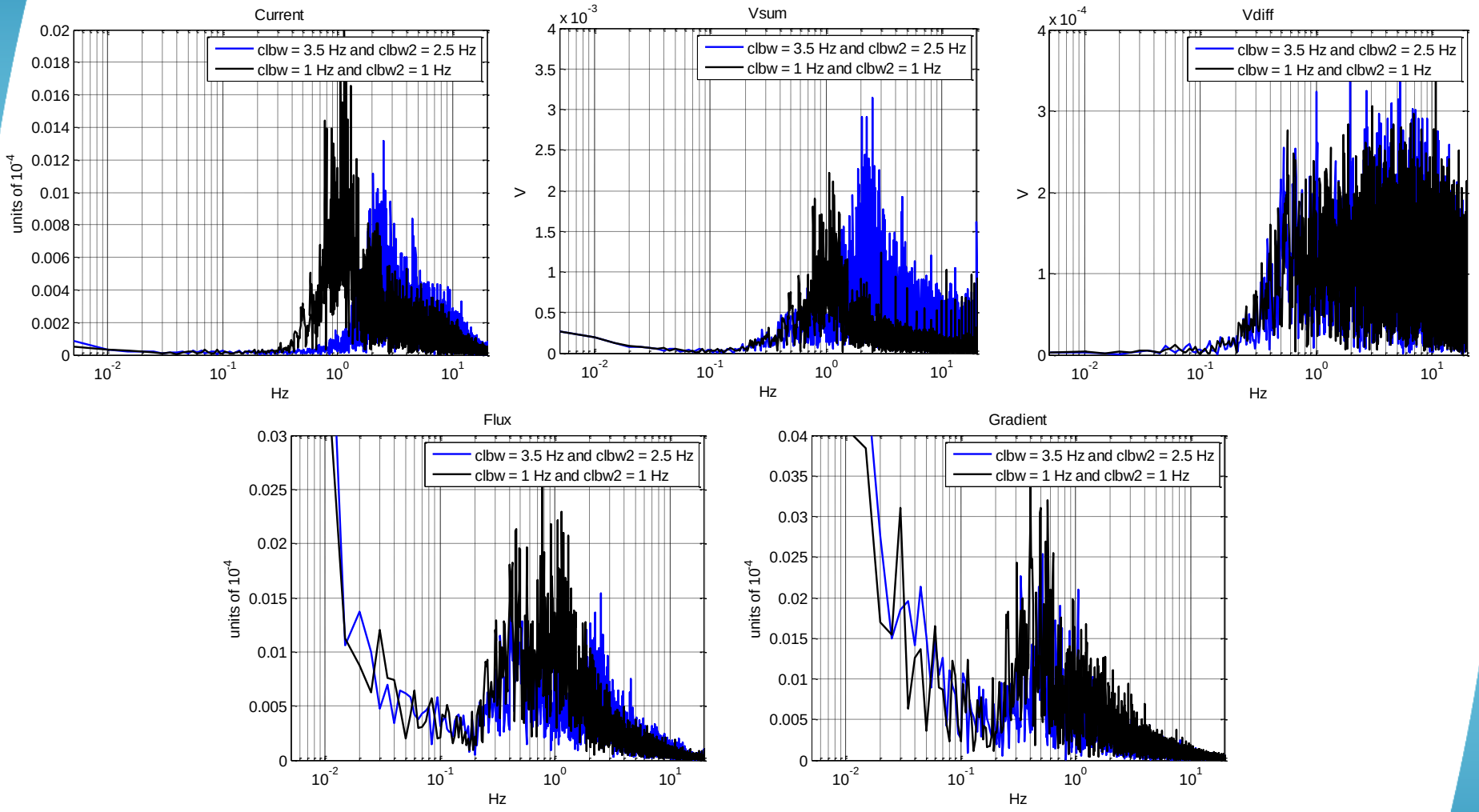




Two different settings for the bandwidth of the filter for rejecting the noise on the current readings:

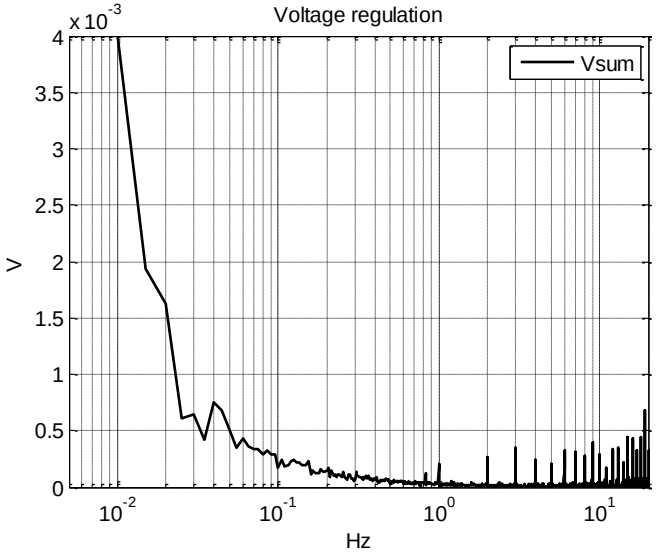
- **clbw 1 Hz**
- **clbw 3.5 Hz**

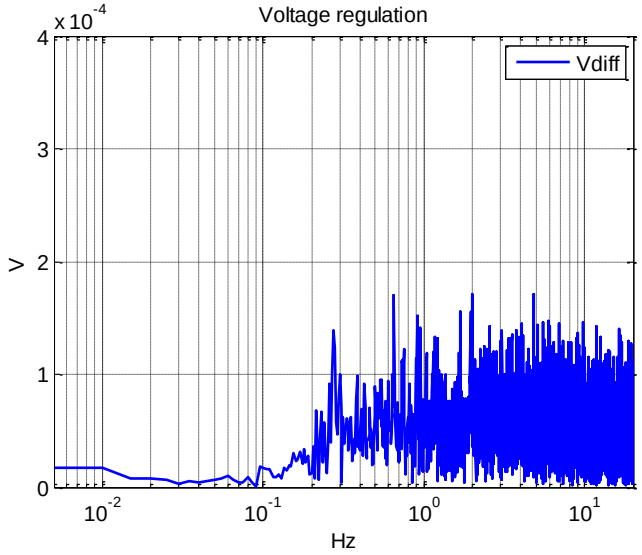
MBHSP109
Study of the effect of the current control



- **Clear shift on the current and Vsum**
- **Some effect on the flux (main field)**
- **No effect on Vdiff and gradient**

MBHSP109
Study of the effect of the current control



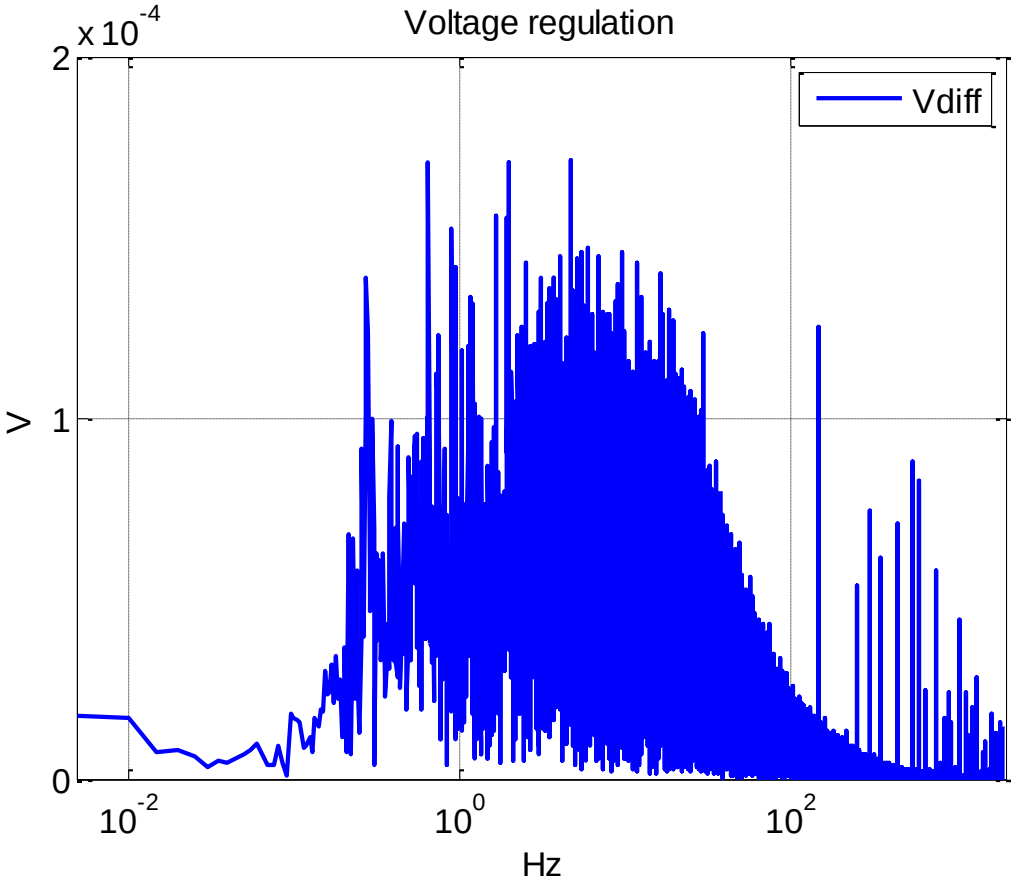


Third case with no regulation on the current, just a voltage reference across the magnet.

With respect to the case with current control:

- **obviously much smaller noise on Vsum**
- **smaller (by a factor ~2) on Vdiff**

Spectrum of the flux jumps



The spectrum of Vdiff, with no control of the current, is only affected by the flux jumps (apart of the harmonics of the converter)

Conclusions

- Flux jumps are visible on the (differential) voltage of all Nb_3Sn magnets tested to date at CERN
  - We have tested many short models but still little experience on “long” magnets
  - From the MBH proto we see same amplitudes as short models on Vdiff
- At the field levels where there is more activity from flux jumps and during ramps at nominal ramp-rate we see:
  - changes of the main field ($1*10^{-4}$)
  - the current is as well affected ($1*10^{-4}$)
  - an up-down gradient ($1*10^{-4}$)
- The control of the current affect the visible effect of flux jumps on current and Vsum
- The bandwidth of the flux jumps, measured on the Vdiff without current regulation, is 0.1-100 Hz