CERN
European Organization for Nuclear Research
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PS main Magnetic field issues Workshop

MPS and PFW regulation

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MiniWorkshop, 23rd February 2012

SUMMARY

POPS

Bfield and Imag starting of a cycle (non zero)

Bfield control loop with rst algorithm

Imag control loop with rst algorithm and saturation compensation

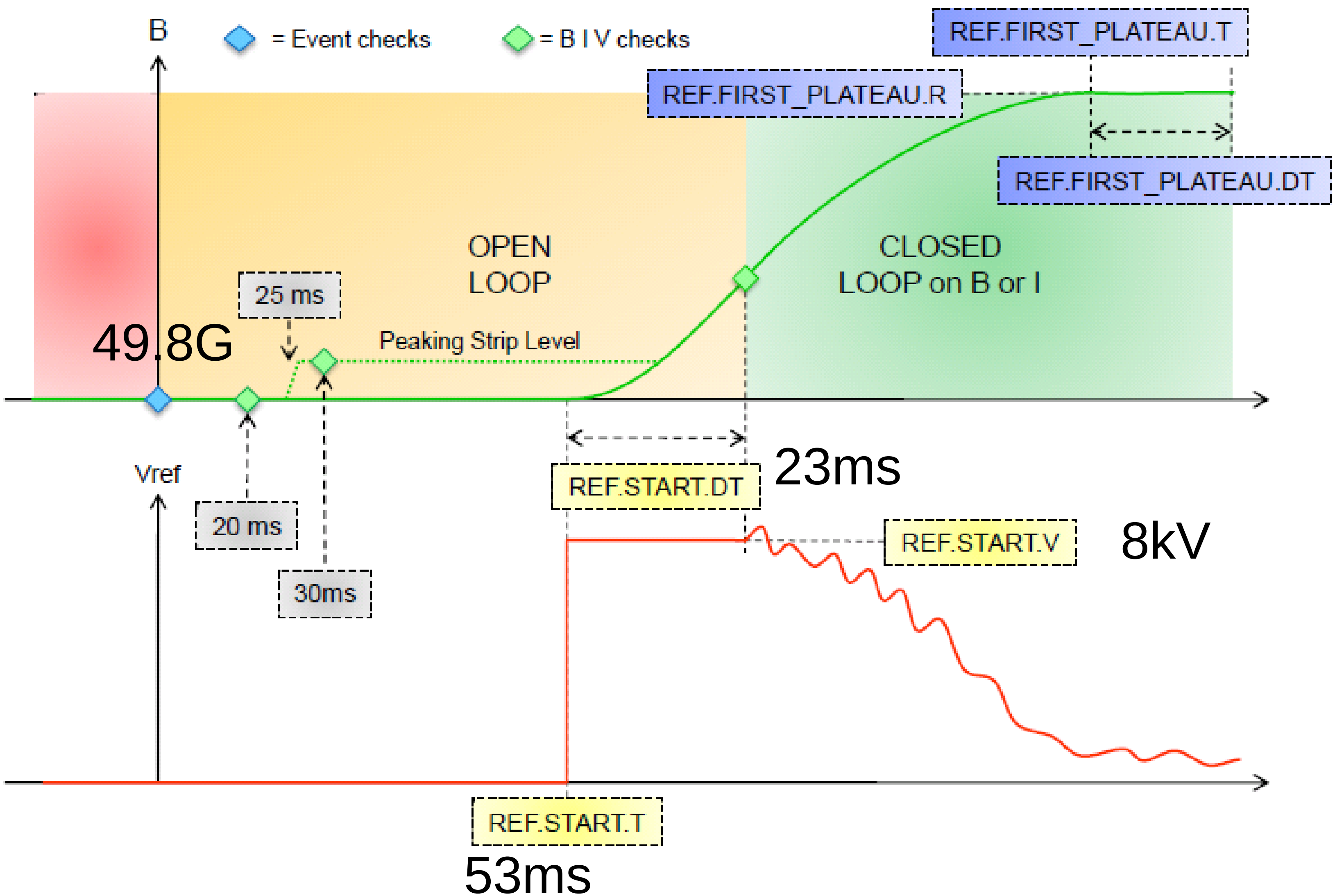
Vout control loop with rst algorithm

PFW and B8

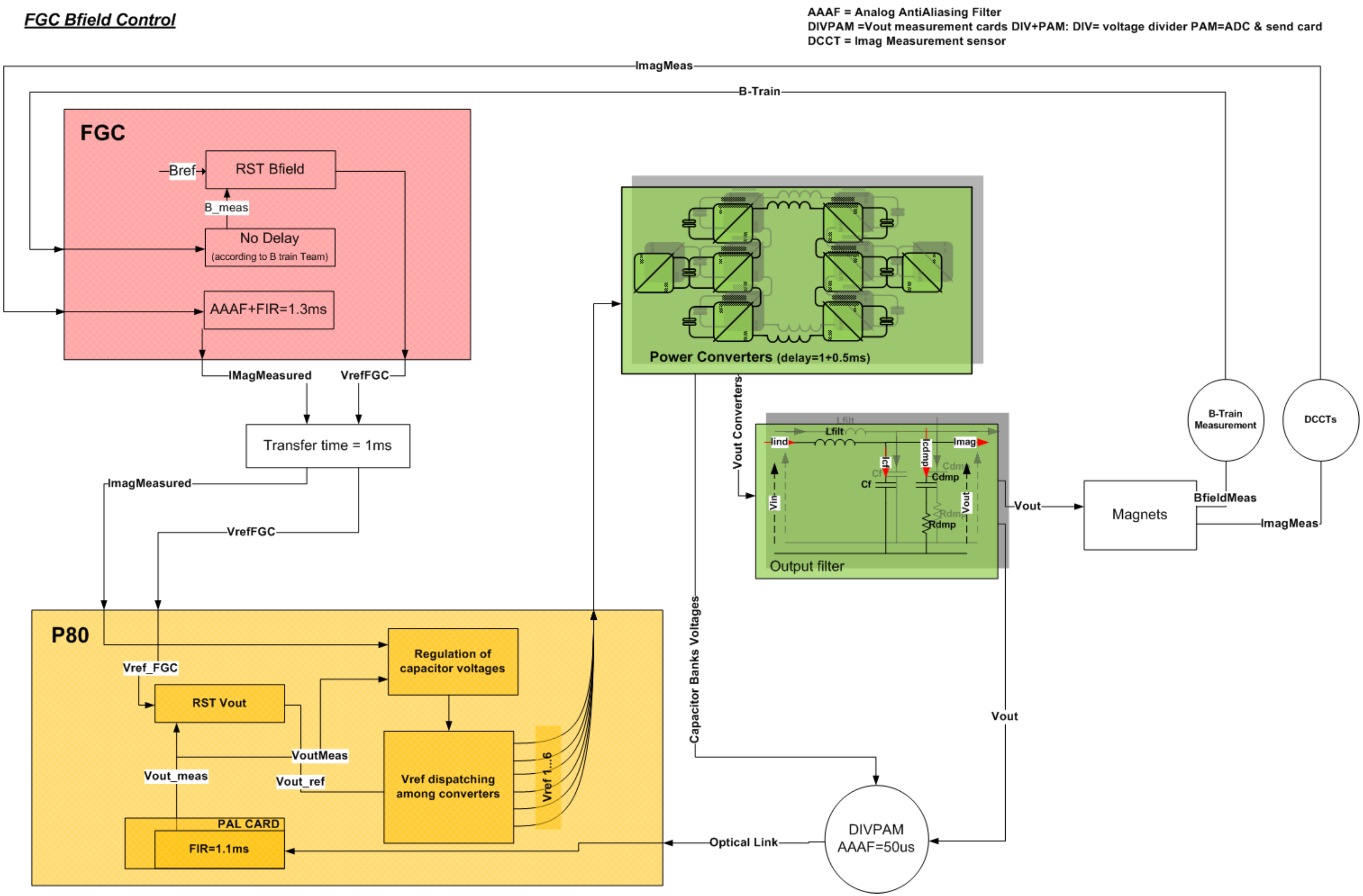
Circuit connection and converter types

General control strategy and means to reduce coupling effects with dipolar magnets

POPS: B or I non zero Cycle Starting

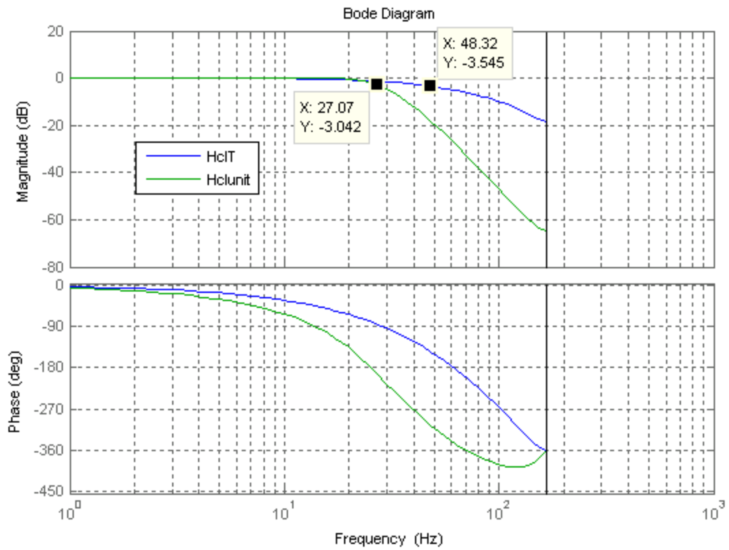


POPS B field regulation: General Schematics



POPS B field regulation

Bfield loop



RST regulator executed in FGC controller.

Tsampl=3ms.

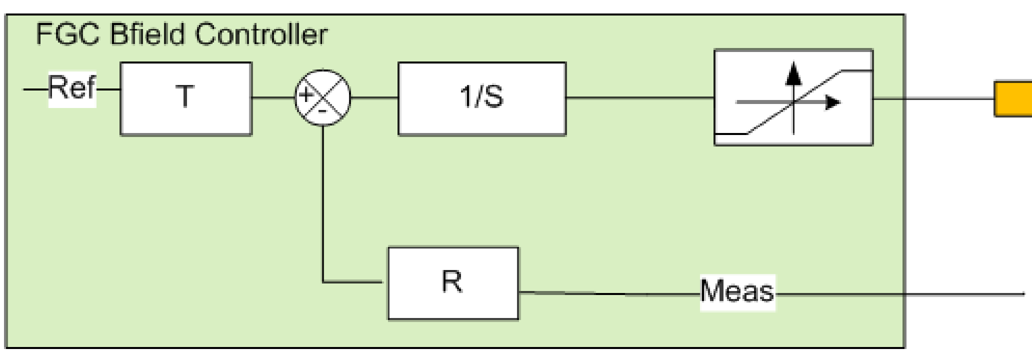
Each polynomial has a maximum of 10 coeffs for a total of 30.

Performance to date (based on theoretical calculations):

Ref following: 48Hz

Disturbance rejection: 27Hz

$$\mathrm{Ref}_0 = \frac{\sum_0^N \mathrm{Act}_i \cdot S_i + \sum_0^N \mathrm{Meas}_i \cdot R_i - \sum_1^N \mathrm{Ref}_i \cdot T_i}{T_0}$$



$$\mathrm{Act}_0 = \frac{\sum_0^N \mathrm{Ref}_i \cdot T_i - \sum_0^N \mathrm{Meas}_i \cdot R_i - \sum_1^N \mathrm{Act}_i \cdot S_i}{S_0}$$

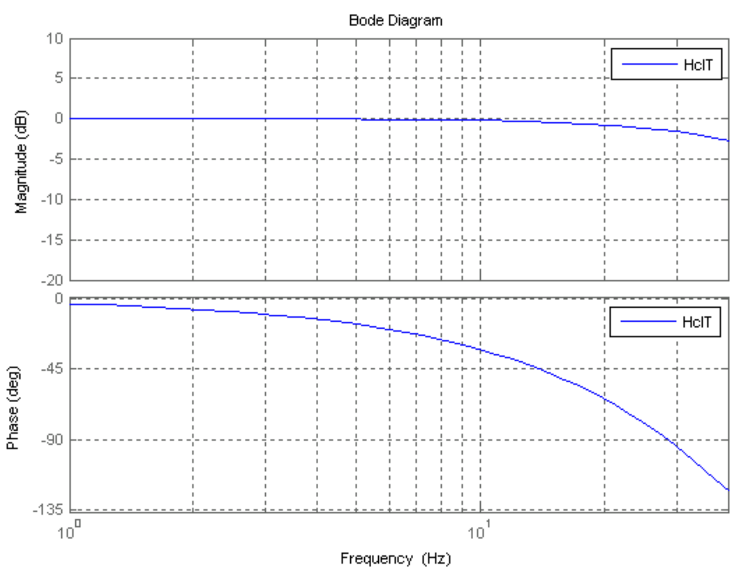
Bfield loop: Tracking delay

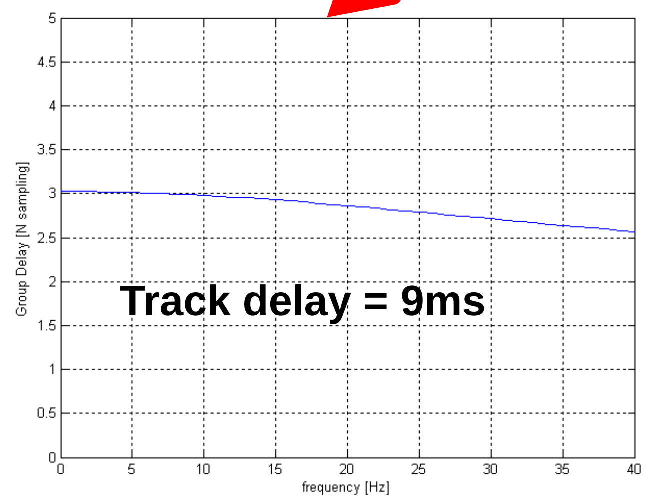
Given that group delay and amplitude response of filter are (almost) constant then group delay may be taken as a pure delay from input to output signal.
This is called Tracking delay in FGC and used to correctly advance the Bref

Complete transfer function (from reference to measure):

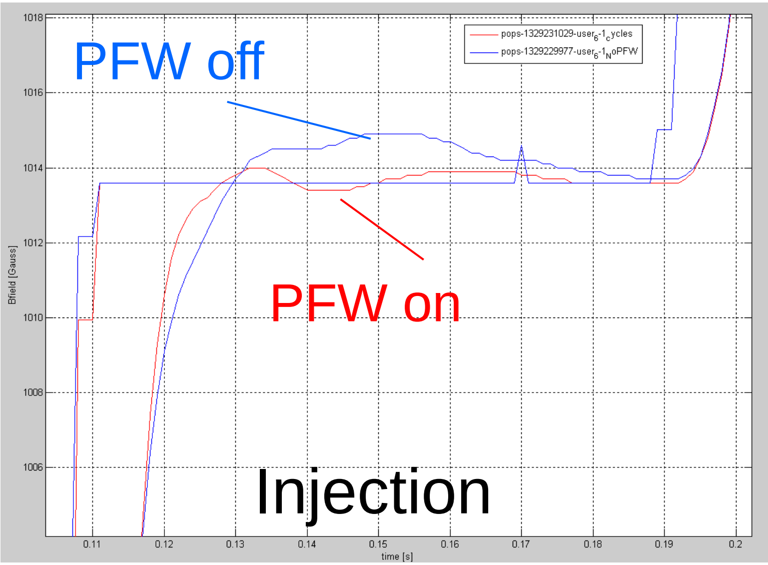
$$HclT = \frac{0.38496 \cdot z^{-2} \cdot \left(1 + 0.5586 \cdot z^{-1}\right)}{1 - 0.4 \cdot z^{-1}}$$

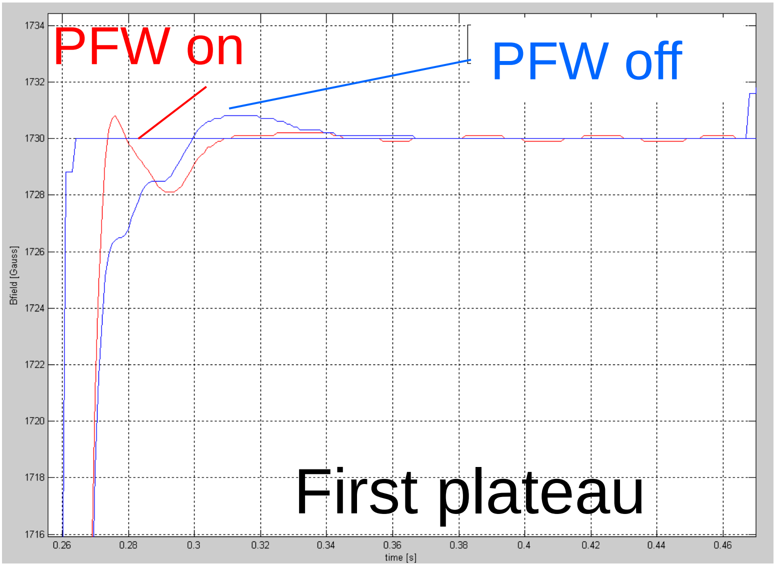
$$Gdelay = \frac{\partial \varphi(\omega)}{\partial \omega}$$

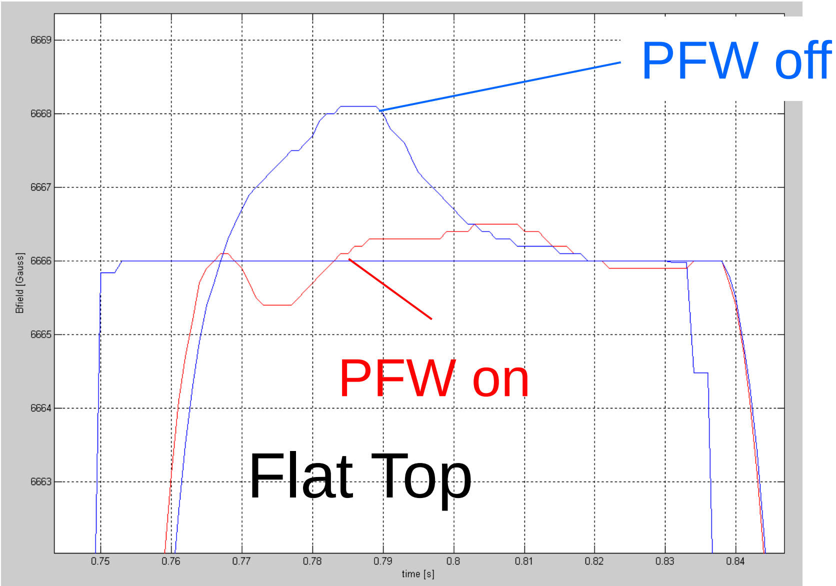




PFW effects on main B regulation (SFTPRO)



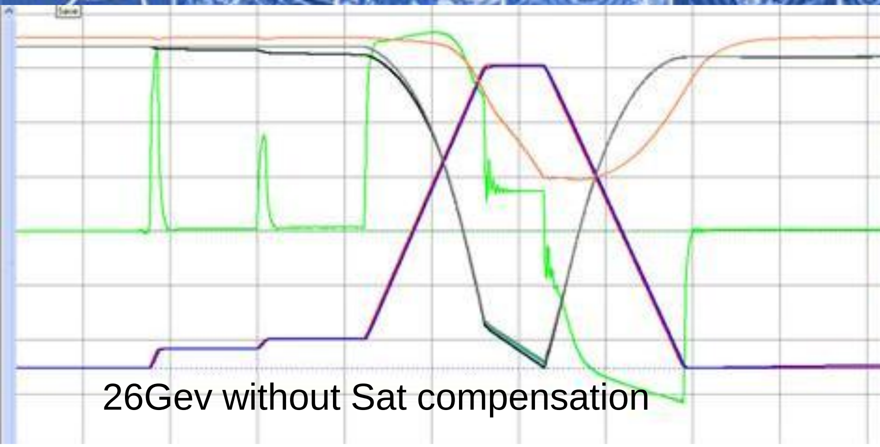


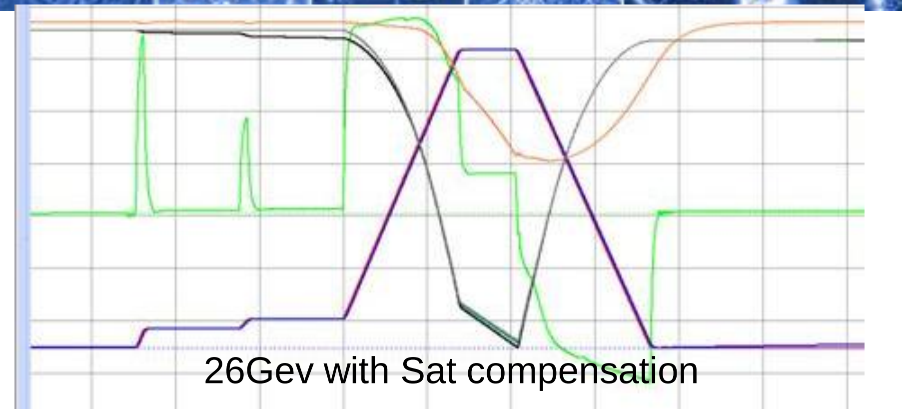


The RST algorithm is tuned with PFW. *No active compensation is introduced in the control.*
If PFW are switched off the behavior is worst because the internal dynamic of the Bfield regulator is not high enough

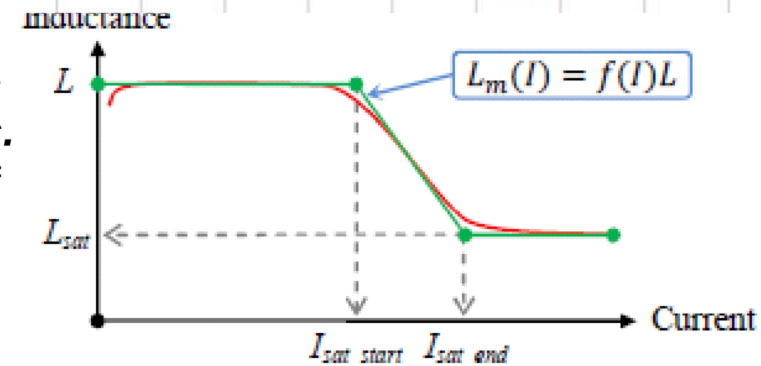
POPS Imag regulation

Imag loop: rst with saturation compensation



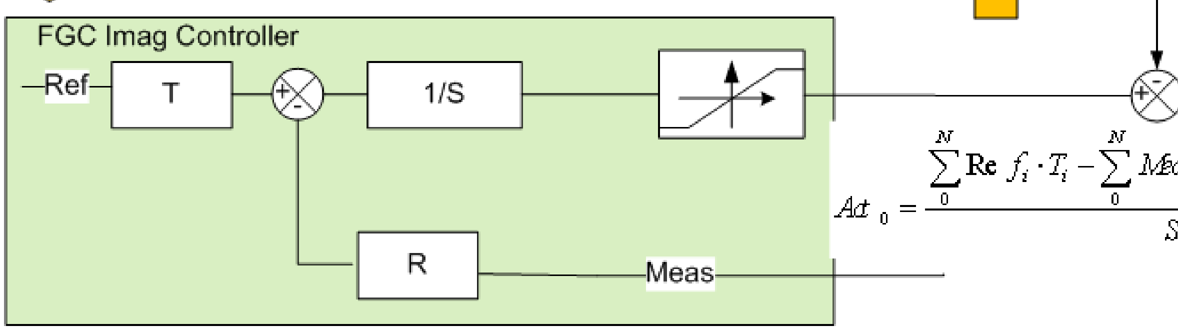


RST regulator with FFW to compensate saturation voltage drops. Executed in FGC (for testing in P80) ***Tsampl=3ms.*** Each polynomial has a maximum of 10 coeffs for a total of 30.



$$\mathrm{Ref}\, f_0 = \frac{\sum_0^N Act_i \cdot S_i + \sum_0^N Meas_i \cdot R_i - \sum_1^N \mathrm{Ref}\, f_i \cdot T_i}{T_0}$$

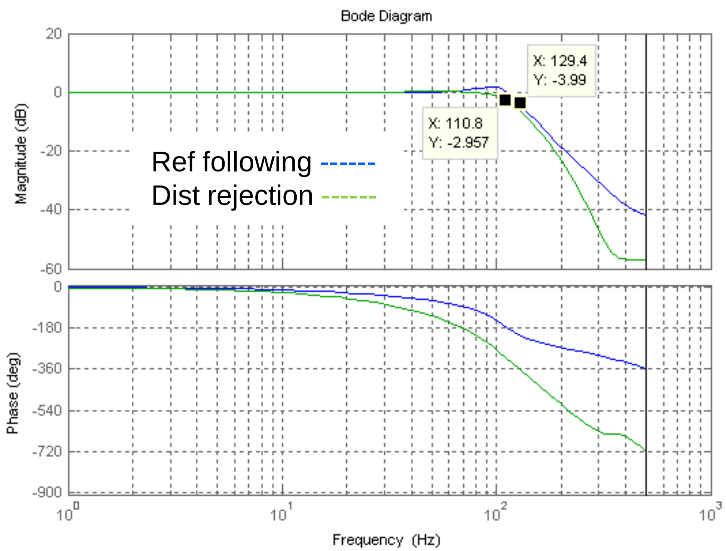
$$delta\_ref = \frac{\mathrm{Im}\,eas - Isat\_start}{Isat\_end - Isat\_start} \cdot (Act_0 - Rmag \cdot \mathrm{Im}\,eas)$$



$$Act_0 = \frac{\sum_0^N \mathrm{Ref}\, f_i \cdot T_i - \sum_0^N Meas_i \cdot R_i - \sum_1^N Act_i \cdot S_i}{S_0}$$

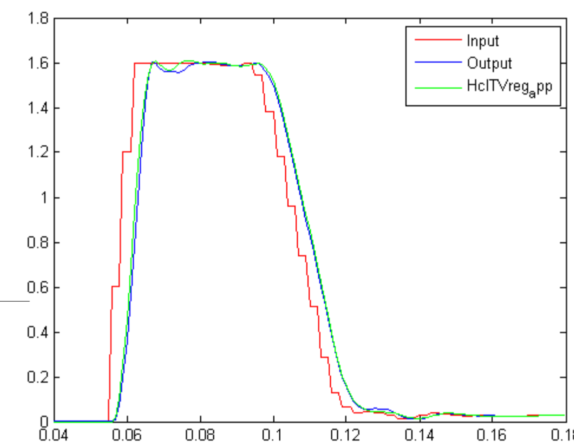
POPS Vout regulation

Vout loop



RST regulator with FFW to compensate for converters voltage drops. Executed in P80. ***Tsampl=1ms.***
Each polynomial has a maximum of 10 coeffs for a total of 30.
Performance to date (identified with initial step response):
Ref following: 130Hz
Disturbance rejection: 110Hz

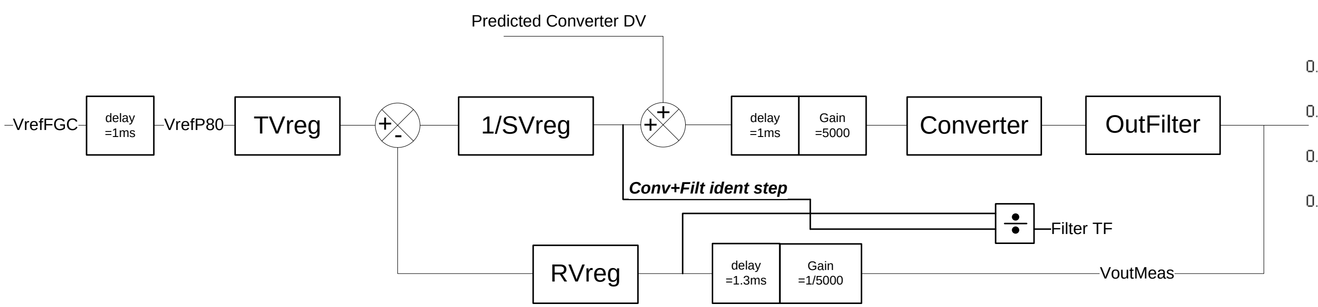
Step identification



This identified TF has been used for Bfield RST calculation

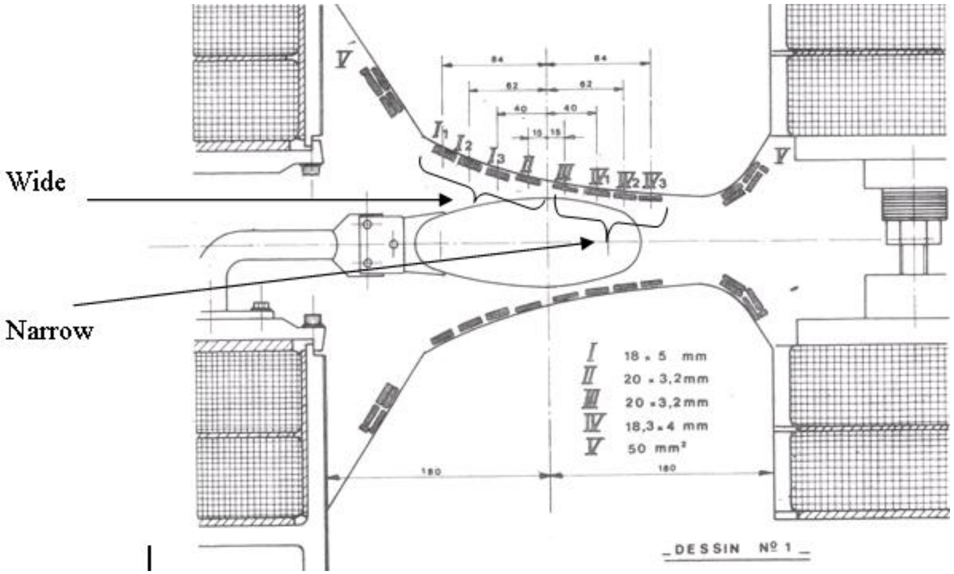
Transfer function:

$$\frac{0.02718 z^2 + 0.08804 z + 0.01852}{z^3 - 1.989 z^2 + 1.587 z - 0.4638}$$



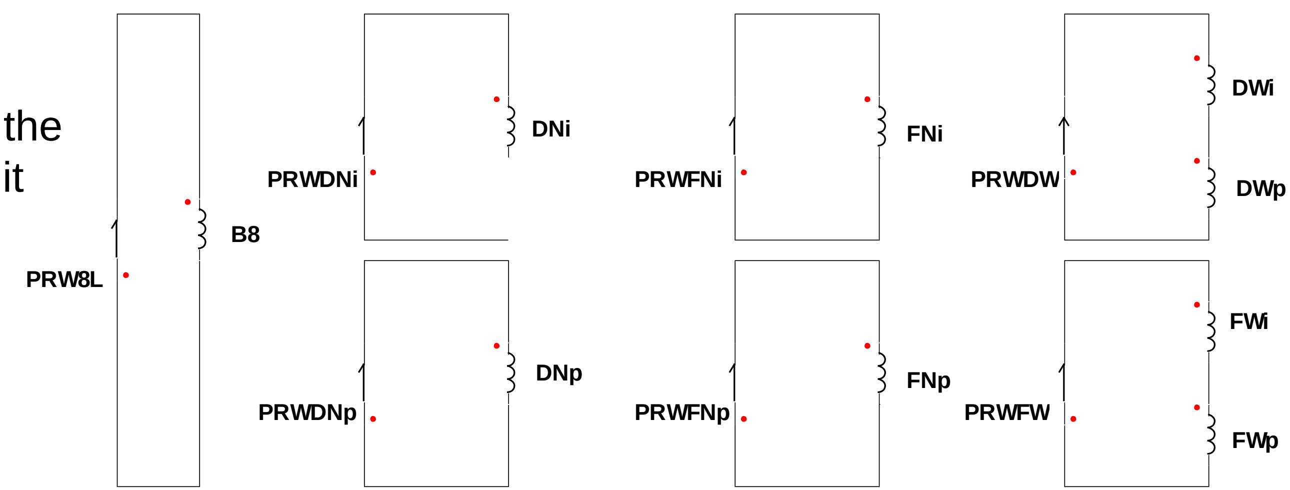
PFW and B8

PFW and B8: circuits connection

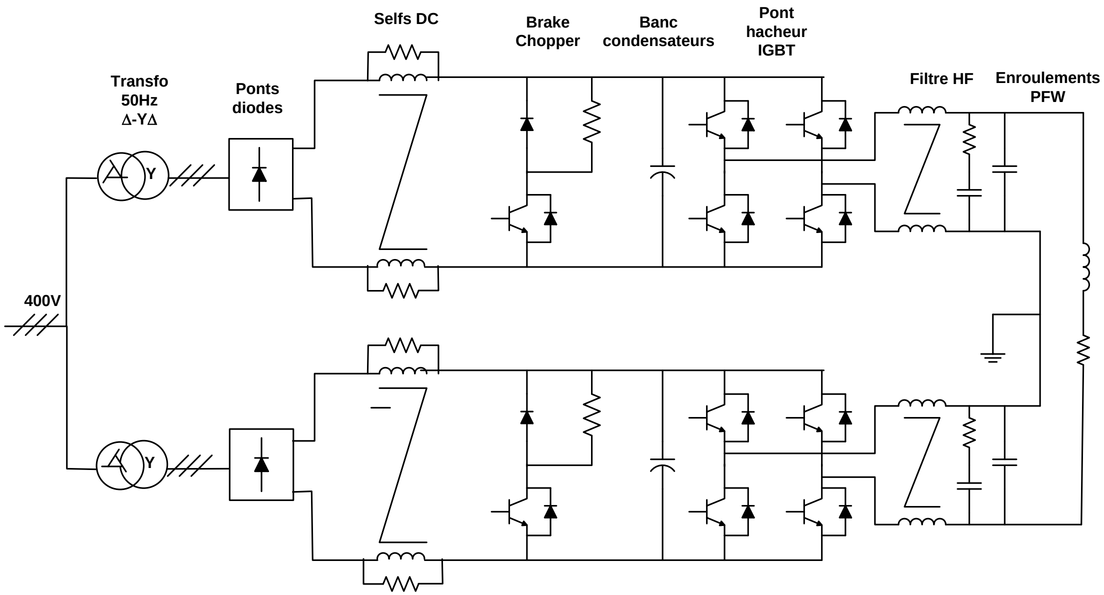


The aux circuits are now connected in the 5 currents mode.
This mode allows more DOF for physics control but no compensation of the induced voltages is realised via the connection.
The emf induced by main dipolar field is a disturbance in the current regulation loop

'I' and 'p' mean even and uneven.
It refers to the numbering of the main magnet along the circuit



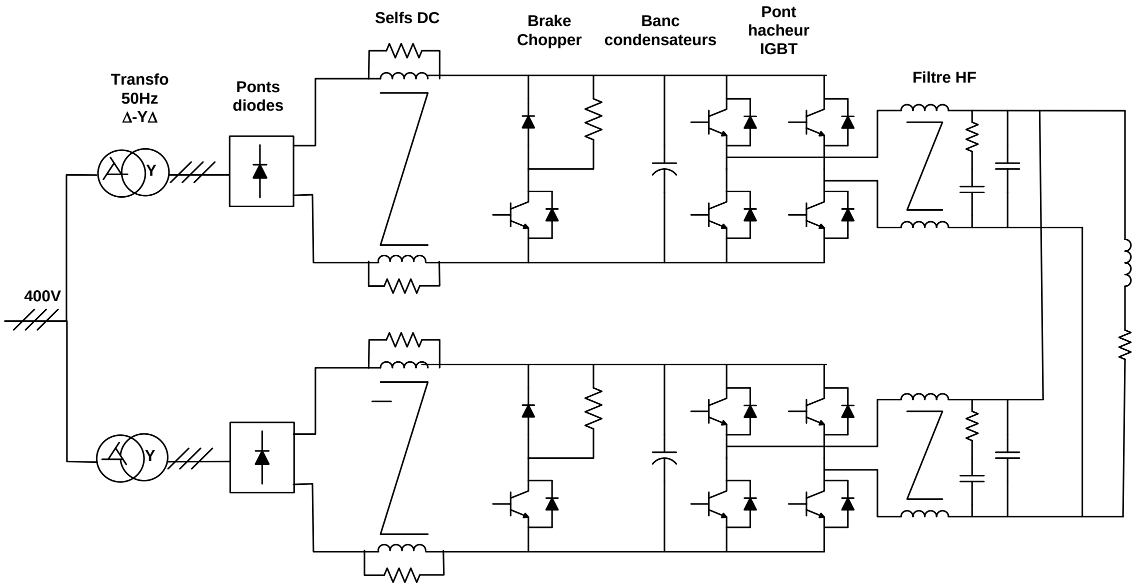
PFW : power supply



2 IGBT bridges connecte in series for PFW circuits

PFW	DNI	DNP	DW série	FNI	FNP	FW série
Résistance, Rmg	3.74 Ω	3.74 Ω	3.32 Ω	3.74 Ω	3.74 Ω	3.32 Ω
Inductance, Lmg	0.034 H	0.034 H	0.008 H	0.034 H	0.034 H	0.008 H
Constante de temps du circuit	0.009 s	0.009 s	0.002 s	0.009 s	0.009 s	0.002 s
Imax	**250 A**	**250 A**	**250 A**	**250 A**	**250 A**	**250 A**
Irms	**80 A**	**80A**	**80 A**	**80 A**	**80 A**	**80 A**
Vmax	**1200 V**	**1200 V**	**1200 V**	**1200 V**	**1200 V**	**1200 V**
Calcul de la tension						
Rmg * Imax_op	374 V	374 V	332 V	841.5 V	841.5 V	747 V
Lmg * di/dt_max	**170 V**	**170 V**	**40 V**	**170 V**	**170 V**	**40 V**
Tension maximale	**544 V**	**544 V**	**372 V**	**1011.5 V**	**1011.5 V**	**787 V**

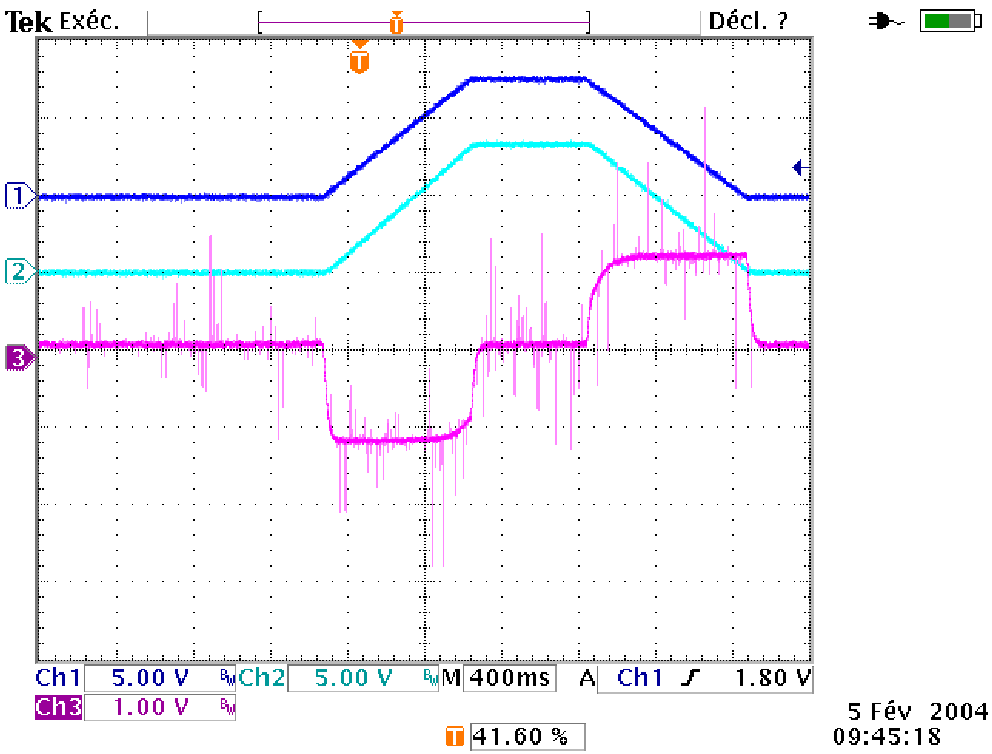
B8 : power supply



2 IGBT bridges connecte in parallel for the B8

PFW	B8
Résistance, Rmg	0.24
Inductance, Lmg	0.012
Constante de temps du circuit	0.050
Imax	1600 A
Irms	600 A
Vmax	600 V
Calcul de la tension	
Rmg * Imax_op	384
Lmg * di/dt_max	**180**
Tension maximale	**564 V**

The emf induced by dipolar field

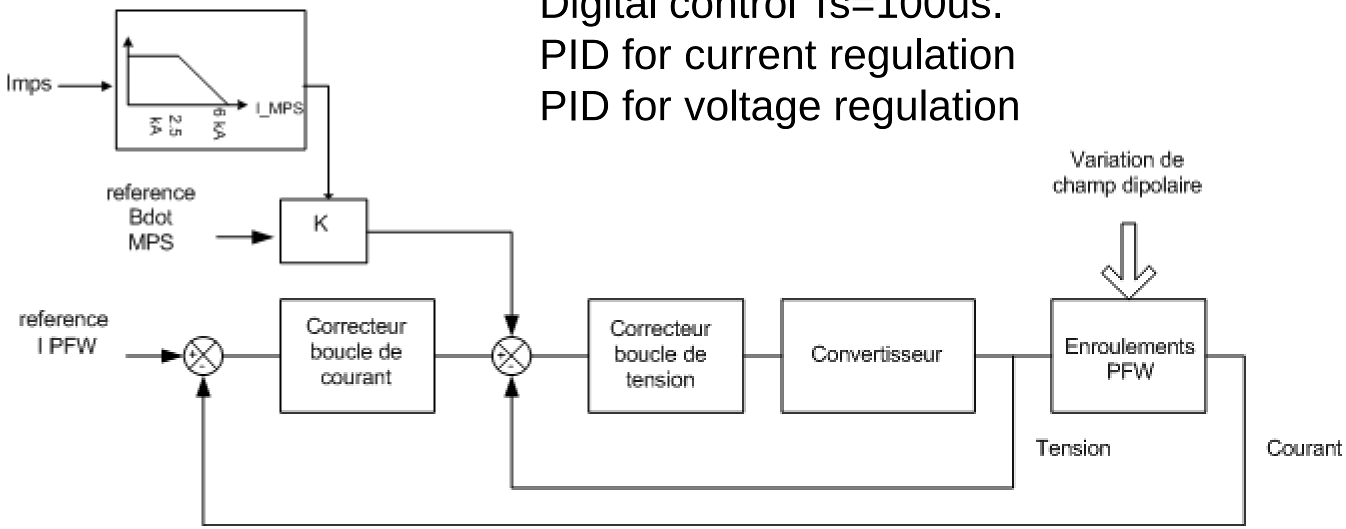


The main dipole current rises from 0 to 5kA with 6500 A/s dynamic

The voltage induced on PFW windings is of the order of 100V (over the complete series connection).
These emf decreases as the saturation of the magnets begins

The control

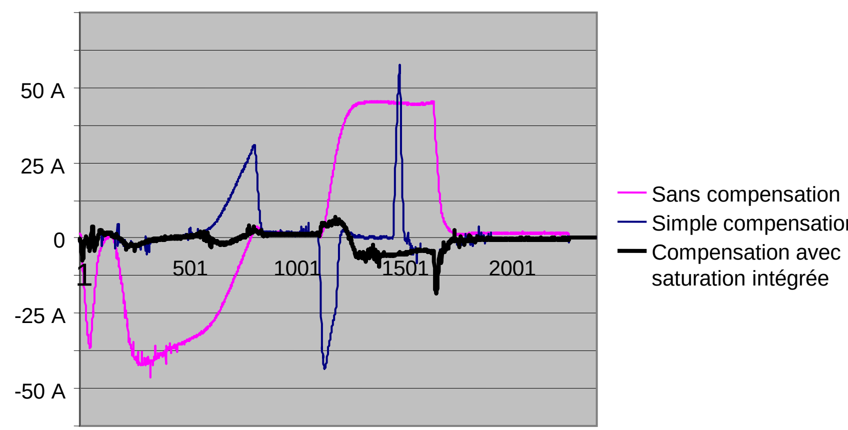
Digital control Ts=100us.
PID for current regulation
PID for voltage regulation



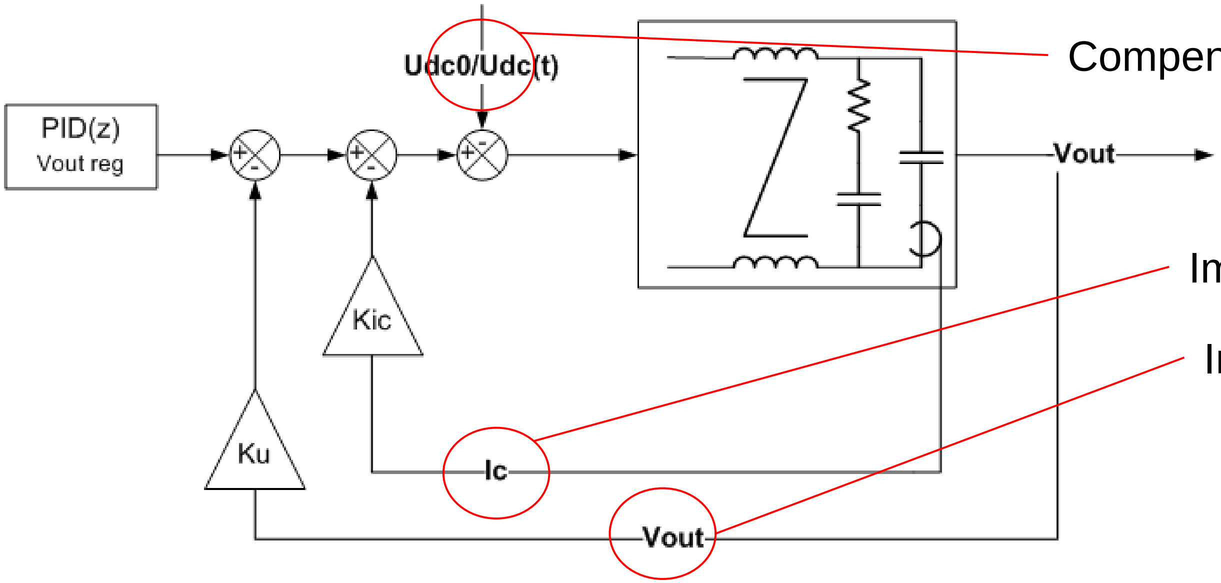
$$Emf_0 = k_1 \cdot \dot{B}_{MPSref} \quad \text{emf without saturation}$$

$$Emf = Emf_0 \cdot \left(I_{MPSsat} - k_2 \cdot I_{MPS}\right) \quad \text{emf with saturation}$$

The reference Bdot from MPS and the measure Imps are used to correct the reference of the voltage loop using a linear correlation between Imps and saturation of the magnets.



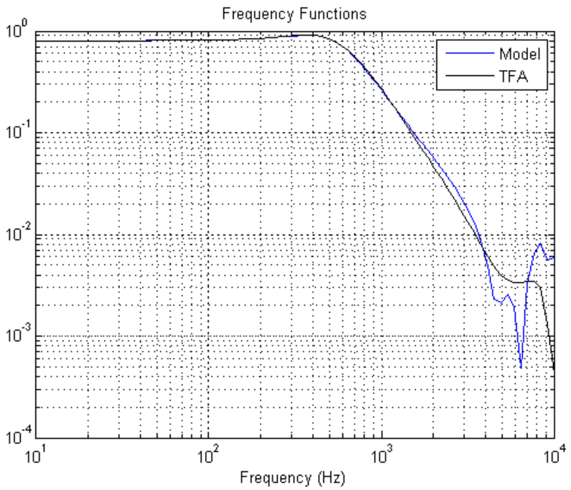
The state reaction

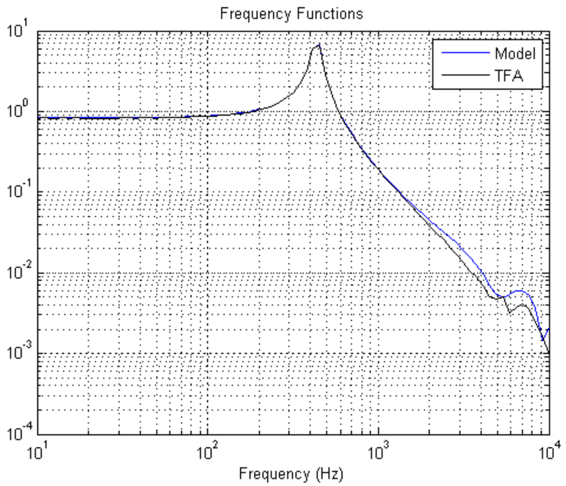


Compensate the (slow) variations of Udc

Improve the dumping of the filter

Improve the dynamic of the filter





Thanks for the attention.

Questions?