ISTTOK poloidal field coils positioning assessment

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FCT PhD PROGRAMMES

Motivation

Correct magnetic measurements are essential for plasma position control and equilibrium reconstruction; therefore, the removal of the external fields from the measurements is paramount. On ISTTOK, the computed external fields do not match the measurements. A possible cause is an incorrect assumption on the active coils positions. Over almost 30 years of operation significant displacements from the original fixture positions are expected. In this contribution, the magnetic measurements are used to assess the effective positions of the polodal field coils.

ISTTOK Poloidal Field Coils (PFC)

ISTTOK

In operation since **1990** at IST
Large aspect ratio tokamak:

- R = 0.46 m
- a = 0.085 m

Small machine with short maintenance down time allows the conduction of edge plasma and liquid metal studies as well as a prime test-bed for **diagnostic development** [1].

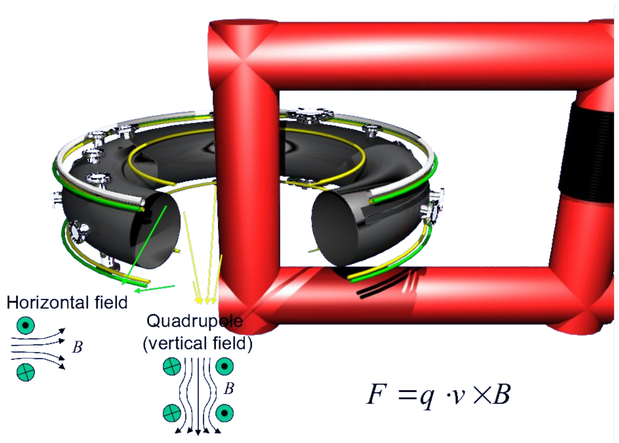


Fig. 1 ISTTOK PFC and iron core. Primary coils represented in white [2].

Three sets of PFC

ISTTOK has 3 sets of poloidal field coils:

- **Vertical** field coils - for horizontal positioning
- **Horizontal** field coils - for vertical positioning
- Transformer **Primary** - to drive the plasma, installed more recently

Digital magnetic diagnostic integrators

The magnetic diagnostic integrators on ISTTOK are similar to those developed at IPFN for long pulse integration on W7-X and ITER [3]. The digital integration provides **accurate** and **reliable** magnetic flux measurements from the poloidal array of **12 Mirnov coils**.

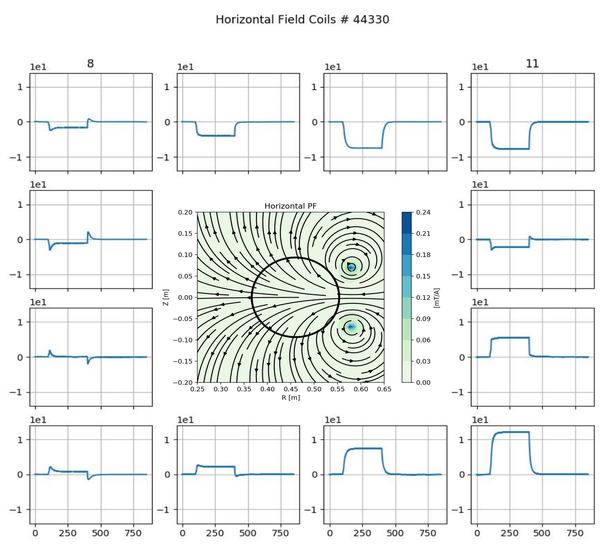


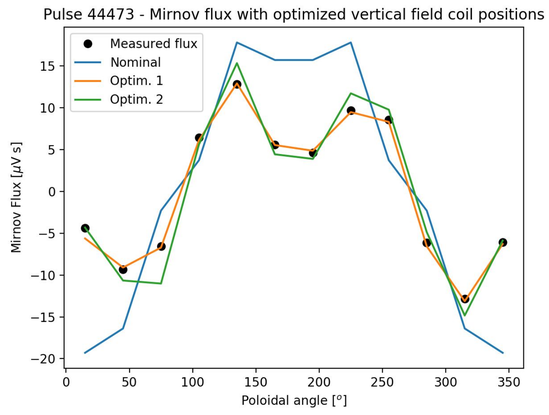
Fig. 2 Mirnov integrated signals for a vacuum discharge with an Heaviside pulse on the Horizontal PFC circuit. In the center, expected field distribution.

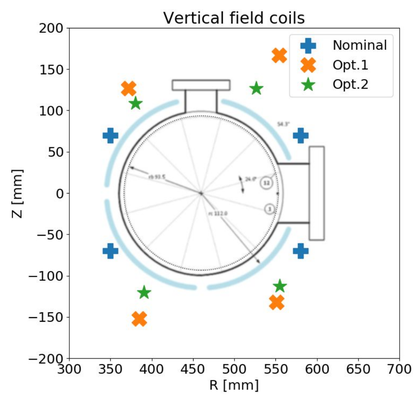
Experimental method

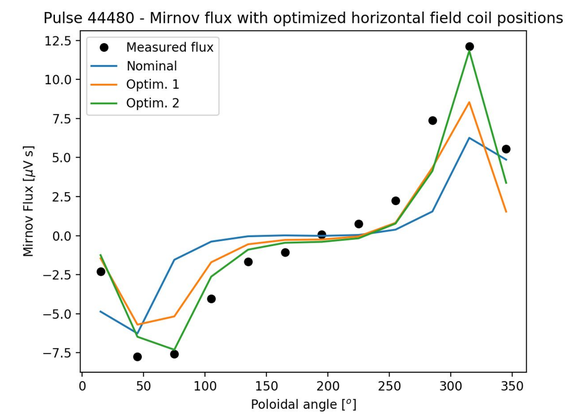
In this study we aim at reconstructing the effective positions for each circuit using the Mirnov integrated signals, by:

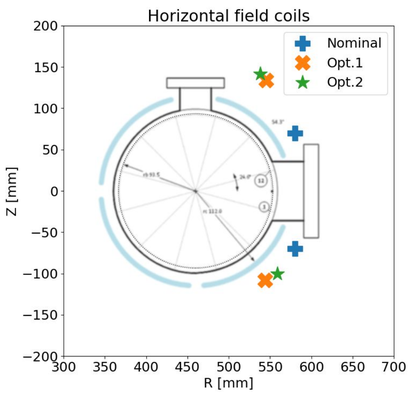
- Vacuum shots with Heaviside pulses on each circuit individually.
- Computing the magnetic field at the probe cross section using elliptic integrals.
- Computing the PFC positions for which the flat-top signal better matches the measured signal.
- Due to the high number of degrees of freedom, an interactive and visual method was used, to find two optimizations:
  - Optimization 1 varying only the PFC positions.
  - Optimization 2 varying both the positions and a gain factor on the current on the PFCs.

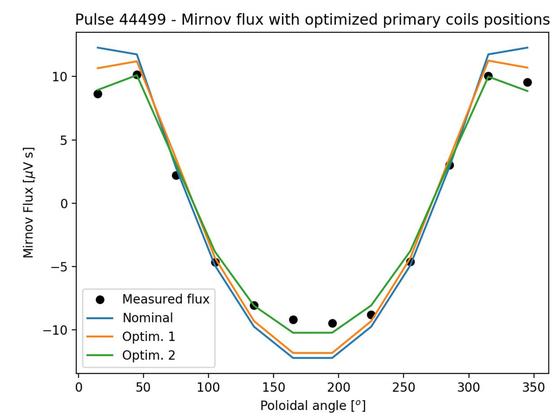
Optimization results











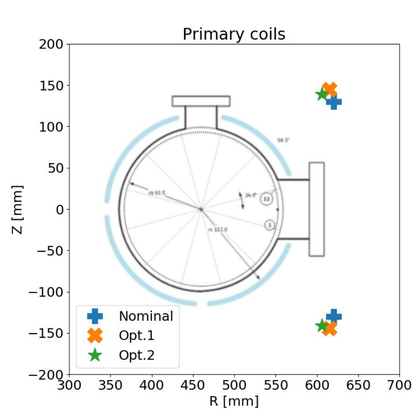


Fig. 3 Left: flat top value of Mirnov integrated signals for a vacuum discharge with an Heaviside pulse on the Vertical, Horizontal field and Primary coils (black) and the expected signal computed using the nominal and optimized positions. Right: representation of positions on a poloidal cross section of the vacuum vessel.

Table 1 Optimization results.

		Vertical				Horizontal		Primary	
Nominal	R [mm]	580	580	350	350	580	580	620	620
	Z [mm]	-70	70	-70	70	-70	70	-130	130
Opt. 1	R [mm]	551	554	385	372	544	545	615	615
	Z [mm]	-132	167	-152	127	-108	134	-144	145
Opt. 2	R [mm]	555	526	391	380	559	588	606	606
	Z [mm]	-113	127	-120	109	-100	146	-141	139
	I gain				0.83		1.324		0.842

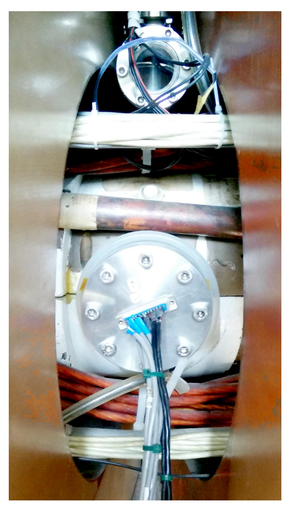


Fig. 4 Photography of a section of ISTTOK showing the Mirnov coils port, the positioning of the Horizontal and Vertical field coils (orange) and the Primary coils (white).

Outlook and conclusions

This study allowed the determination of two sets of positions for the PFC.

- The primary windings, put in place more recently, need much smaller corrections, as expected.
- The optimized positions need **further validation**, but provide a good explanation for the **asymmetries in the magnetic field measured** in vacuum shots.
- These optimizations can be used for the calculation of the field inside the vessel, as they could result in a **more accurate** estimation and a **better agreement** with the measured data.

References:

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[3] Batista, A.J.N, et al., "F4E prototype of a chopper digital integrator for the ITER magnetics", Fusion Engineering and Design, **123** (2017), 1025-1028

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