Plasma energy measurement with diamagnetic loops in the TJ-II stellarator

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TJ-II is an almost shearless, heliac type, stellarator. It is medium sized (R=1.5 m, <a>≤ 0.22 m, B (0) 1 T). Its outstanding configuration flexibility allows performing wide $\iota/2\pi$ scans (0.9 $\iota/2\pi(0)$ 2.2). TJ-II plasmas are produced by means of ECRH (2 gyrotrons 300 kW each, 2nd harmonic X-mode, 53 GHz) and, so far, one NBI injector (H^0, 28 kV, 200-300 kW, pulse length 100-200 msec)

The measurement of the diamagnetic plasma energy is performed by means of two sets of diamagnetic loops installed inside the vacuum vessel at two stellarator symmetric positions. Both sets consist of a main coil, which encircles the plasma column and a compensating coil, which measures only the vacuum magnetic flux. Both coils are nominally coplanar. The existence of a groove that protrudes inside the vessel to allocate room for the central conductors placed outside the chamber restricts and hinders the design of this diagnostic in TJ-II. Each main coil has 6 turns of Thermocoax mineral insulated cable, composed of 0.34 mm diameter zirconium copper conductor, 1 mm outer diameter stainless steel sheath and magnesia in between as insulation. The same material is used to wind the 18 turns of each corresponding compensating coil. The total effective vacuum magnetic flux encircled by both main and compensating coils is 1.1 Wb.

Time traces from each coil are obtained by digitising the corresponding voltage signals for the whole plasma discharge at 10kS/s. Then diamagnetic and compensation signals are off-line subtracted, integrated and base line-compensated to extract the time evolution of the plasma energy content. Typical obtained values are in the range of 1kJ and are usually larger than the kinetic energy values obtained from Thomson Scattering profiles.

The main experimental problems found for this diagnostic in TJ-II are:

- Insufficient compensation of the small current ripple present in the currents supplied by the TJ-II power system. One can distinguish "fast" (about 1 kHz, relative amplitude 10^{-4}) and “slow” (about 30 Hz, relative amplitude 10^{-3}) frequency harmonics present in the external vacuum field. This fact is still not properly accounted for but it has to do with the different influence on both loops (small phase difference due to different time constants) of the currents induced in the (geometrically very complex) vacuum vessel. This problem introduces an absolute error of about 0.2 kJ in the diamagnetic energy.

- Coupling of the loop signals with the plasma current causing severe perturbations in cases of "high" plasma current (OH -driven current, high suprathermal fluxes...) or "long" pulses (base line no longer straight). This problem is caused by small relative misalignments of the two coils.

Diamagnetic and kinetic energy values will be compared and the above mentioned problems will be discussed at the Workshop.