Real-time equilibrium reconstruction integration into the ASDEX Upgrade control system

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The real-time equilibrium reconstruction code for the ASDEX Upgrade tokamak, JANET [1], is in the process of migration to a Linux based C11++ code. This is motivated by the need for closer integration into the control system and the long term goal of replacing the currently used function parameterisation based control when upper divertor coils for studying advanced magnetic configurations are installed [2].

The benchmarks of the individual elements are presently being optimised. The parameters for the position and orientation of the magnetic probes and flux loops, the position of the poloidal field coils and limiters and the surface locations of the 7 rows of ferromagnetic tiles installed in 2017 are input from an XML based machine description file. The setting up of the 12 basis current functions on the flux matrix from the previous time step requires 105 μs. On a 65x129 grid, the Grad-Shafranov solver then calculates a solution in 130 μs that is a best fit to the magnetic probe measurements. Contour integrals at 10 normalised radii required for input to the RAPTOR code [3] and at the separatrix to calculate beta poloidal and plasma inductance are carried out in 100 μs.

Integrators for magnetic probe arrays at 4 additional toroidal locations have been developed. The 16 bit ADC's of the integrators can acquire data with a sample frequency up to 100 kHz and with a software selectable integration time. There are 16 channels in a crate with an interface card and four crates are connected to a PXIe 7821 FPGA. The recorded data is transmitted in real-time by an optical bus extender (MXI Express x4) to the computing node with an 8 core Intel Xeon E5-2667 v3 running at 3.2 GHz.

References

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[3] F. Felici, O. Sauter, S. Coda, et al., Real-time physics-model-based simulation of the current density profile in tokamak plasmas, Nucl. Fusion 51 (2010) 083052.