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Real Time Control of Electron Density on RFX-mod Tokamak Discharges.

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A system for electron density control on tokamak plasma discharges of the RFX-mod experiment (R/a=2.0/0.46m, toroidal field up to 0.55T, plasma current up to 150 kA), has been developed, implemented and subsequently routinely used during experiments. The system has been developed by integration of the existing infrastructure, without further additions of new hardware. This paper describes the design choices, the structure of the components and the result obtained.
The controller itself has been added as a GAM class (Generic Application Module) under the MARTe (Multi-threaded Application Real-Time executor) real-time framework working on RFX-mod at 5 kcycles/sec and controlling the gas puffing system through UDP commands at 250 cycles/sec. The GAM controller consists of a basic PI controller embedded in a state machine, to deal with either the hysteresis of the gas puffing valves and the plasma state changing behavior.
Suitable gains for the PI controller have been determined using a Spice model for the whole system, in order to obtain a satisfactory behavior in very different conditions due to the first wall loading of neutral gas, which slightly increases after each shot. When the first wall is close to saturation and the density becomes uncontrollable, a glow discharge cleaning is performed to reduce the hydrogen wall content.
The average electron density is measured as the ratio between the total diamagnetic pressure, obtained by toroidal field flux sensors, and the electron temperature, obtained by double filter technique from soft X ray diagnostic. This solution gives a robust real-time estimate for the electron density, even if the measurement itself is less precise than the other main techniques like interferometry, which are difficult to implement in real-time and often suffer from measurement failures (like fringe jumps) which requires post pulse processing to be corrected.
After deployment the system has been used to control the density in quite different plasma scenarios: circular and diverted X-point shapes with q(a) > 3, circular shape with q(a)~2, and with L-H mode transitions induced with a biasing electrode. All these configuration correspond to a significant change in the behavior of the density, which the system has been able to properly handle.

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