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The MAST Upgrade Plasma Control System

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MAST has undergone a substantial upgrade [1], featuring among other things several new poloidal field coils mostly distributed around the new closed-throat divertor structure and an enlarged centre column. The considerable changes have required the plasma control software to be substantially re-written.

The MAST digital plasma control system [2] was based on an architecture developed by General Atomics [3]. The legacy hardware presented in the original publication has already been replaced so only some additional I/O was required for MAST-U. The generic software infrastructure from GA has been retained for MAST-U but the tokamak-specific algorithm software has been completely reimplemented to provide the necessary flexibility to support the additional capabilities of MAST-U, especially in the areas of coil current control and gas injection control.

MAST Upgrade has very many gas injection nozzles, driven from 48 Piezo actuator valves, which are arranged in 11 toroidally symmetric groups and supplied with gas via 6 separate plena. The design brief was to provide the flexibility to perform multiple simultaneous gas injection control tasks, any of which can be mapped to any of the 11 valve groups or a combination thereof. Gas flow in a group should be symmetrically balanced whilst taking account of the calibrated flow capability of each active valve for the given plenum pressure and species. The software was also required to prevent usage conflicts or inconsistencies between the gas species assigned to the control task and that present in each of the plena supplying the assigned valve groups. This design requirement was fully met by defining a set of categories (which provide placeholders for pluggable algorithms) for each control task, all making requests to a central gas algorithm that manages the configurable mapping of tasks to valve groups. Details will be presented.

Since the primary focus of the upgrade is to support divertor research, many of the additional PF coils are to control the X-point and/or the trajectory and expansion of the divertor leg. The software architecture for controlling all these coils was partly inspired by the solution chosen for the gas system, where coils can be combined into virtual circuits according to the plasma property to be controlled by that circuit. Multiple control categories have been defined to allow each category to support a choice of control schemes for the virtual circuits it manages independently of what the other control categories are doing. Again, details will be presented.

[1] W. Morris et al, "MAST Upgrade Divertor Facility: A Test Bed for Novel Divertor Solutions," IEEE Transactions on Plasma Science, vol. 46, no. 5, pp. 1217-1226, 2018.

[2] G. McArdle and J. Storrs, "First results from the MAST digital plasma control system," Fusion Engineering and Design, vol. 71, no. 1, pp. 59-64, 2004.

[3] B. Penaflor, J. Ferron and M. Walker, "A Structured Architecture for Advanced Plasma Control Experiments," in Fusion Technology 1996, Proceedings of the 19th Symposium on Fusion Technology, Lisbon, Elsevier, 1997, pp. 965-968.

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