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Distributed digital real-time control system for the TCV tokamak and its applications

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A key feature of the new digital plasma control system installed on the TCV tokamak is its possibility to rapidly design, test and deploy real-time algorithms. It accommodates hundreds of diagnostic inputs and actuator outputs, and offers the possibility to design advanced control algorithms with better knowledge of the plasma state and to coherently control all TCV actuators, including poloidal field coils, gas valves, the gyrotron powers and launcher angles of the electron cyclotron heating and current drive system together with diagnostic triggering signals. It encompasses plasma control applications ranging from basic experiments of coil current and density control to advanced experiments of MHD and plasma profile control. The system consists of multiple nodes, each of which may have a local ADC and/or DAC card; all nodes are connected to a memory network (reflective memory), providing a deterministic method of sharing memory between them. Recently, a generalized plasma position and shape controller based on the real time Grad-Shafranov solver RTLIUQE was developed and implemented, providing the basis for future high performance plasma operation with advanced plasma configurations. The controller design is based on an isoflux control scheme and utilizes singular value decomposition (SVD), to respect the limits on poloidal field coils currents by limiting the controlled parameters to the set that can be more easily controlled. The controller is capable in principle of providing improved equilibrium control especially for unconventional plasma scenarios, for e.g. reliable control of 'snowflake'equilibria with closely spaced x-points, i.e. the 'exact'snowflake, and the development of negative triangularity plasmas in H-mode. An addition of a new node on the digital control system has enhanced the real time computational capacity and hosts the real-time transport code RAPTOR (RApid Plasma Transport simulatOR), an advanced density profile reconstruction algorithm including real-time fringe jump correction, as well as a plasma state monitoring, supervision and actuator management algorithm. In future, more signals from existing TCV diagnostics, including multiview pinhole X-ray diagnostics, Thomson scattering, visible image processing and magnetic signals for MHD mode analysis will be added to expand the capabilities of the digital control system.

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