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Overview of the TCV digital real time plasma control system and its applications

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TCV has a flexible, digital, distributed control system for testing experimental control algorithms, acquiring data from hundreds of diagnostic channels and controlling all magnetic, heating and fueling actuators. We present the state of the system, focusing on the latest upgrades, and the key control capabilities enabled by the system. The control algorithm code is developed and maintained in MATLAB/Simulink and run-time code is generated automatically using code generation. The previously used practice of just-in-time code generation and compilation before every shot has been abandoned in favor of a more reliable and efficient method where the run-time code is able to load parameters and waveforms from plant databases. The ability to simulate the control code is guaranteed by an object-oriented simulation framework in MATLAB/Simulink that reads parameters and waveforms from the same databases w.r.t. the real-time environment. This approach still allows very rapid development and deployment cycles with new algorithms deployed on TCV usually within a few days from the completion of their testing in simulation. The control algorithm software is managed through a DevOps methodology with extensive unit and regression tests as well as Continuous Integration / Deployment practices.
The real-time environment has been completely replaced by the F4E MARTe2 framework, greatly improving standardization, modularity, maintainability and extensibility. The intrinsic data-driven application runtime buildup of the MARTe2 framework has naturally yet rigorously allowed the integration of the inter-shot tunable parameters and waveforms in the control code. The framework has also greatly enhanced interfaces between the real-time computers and the rest of TCV IT infrastructure, notably with its databases for shot configuration and control data acquisition.

From the point of view of the hardware, the systems responsible for primary plasma controls (magnetic control and density control) have been upgraded with new ADC/DAC modules connected to two real time computers operable in parallel on the same discharge. This arrangement allows to use one control computer for the primary (released) main plasma controller while the second one can be used as a live test stand for plasma algorithms in state of testing or development. Also, a new EtherCAT real time industrial network has been laid down to operate distributed low I/O count subsystems boosting system flexibility at low additional cost and high speed of commissioning.

This overhauling process has already granted a number of experimental advances on the machine, the foremost ones being: SAMONE a comprehensive real-time plasma supervision, off-normal event handling and actuator management system, plasma event detectors based on neural networks, novel linear controllers for improved vertical control for the formation and stabilization of doublet. Finally a number of existing real-time codes have already been ported to this new approach allowing them to be run seamlessly on every TCV discharge in real-time; notably they comprise RT-LIUQE, the real-time magnetic equilibrium reconstruction of TCV, coupled with real-time transport calculations; RT-MHD, the comprehensive real-time MHD analysis algorithms set and real time divertor radiation front control with multispectral 2D imaging diagnostics (MANTIS). Other applications include runaway and profile control.

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