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Integration of a Real-Time Node for Magnetic Perturbations Signal Analysis in the Distributed Digital Control System of the TCV Tokamak

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Motivation

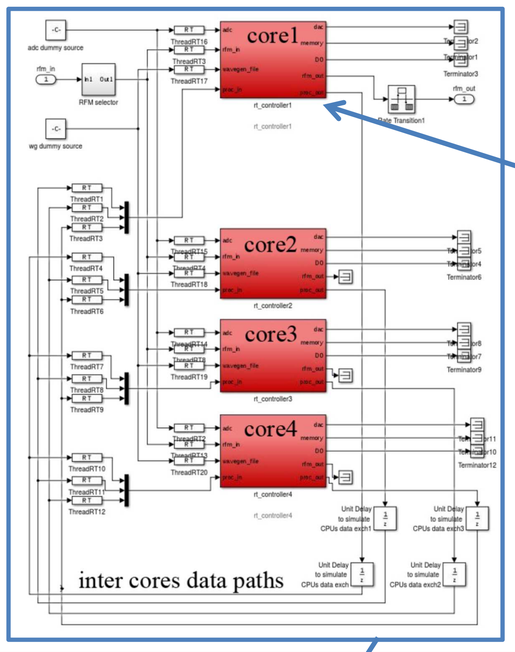
- The analysis of fast magnetic signals measured by magnetic probes installed on a tokamak vessel has been widely employed to detect and analyze a number of plasma instabilities, notably rotating tearing modes after plasma discharges [1-4]. These provide copious information on magnetic islands topology, size and evolution for instance.
- The integration of these techniques into the TCV digital real time control system allows the execution of advanced magnetic analysis codes during the tokamak discharge.
- The final goal is to provide plasma health status information to decision making algorithms that can initiate actuator reactions to prevent major plasma instabilities, notably high current plasma disruptions.

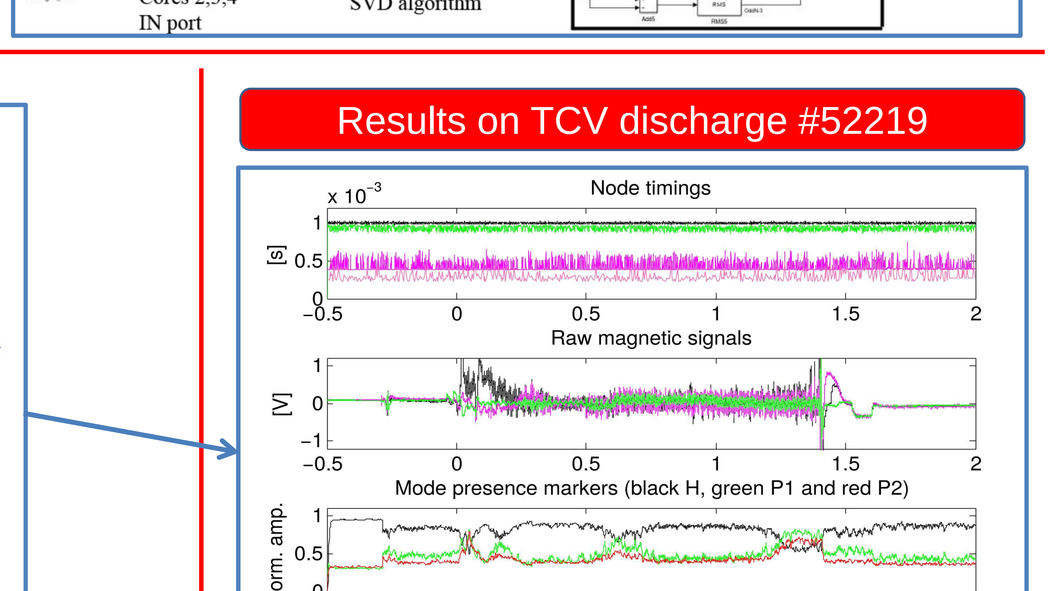
Highlights

- Integration of a new node in the distributed digital control system of the TCV tokamak tailored to the execution of advanced analysis algorithms on the magnetic signals in real time.
- On the field demonstration of a real-time packet acquisition and processing approach, multi-core data processing and data transfers on a multi synchronous system.

Implemented tearing modes presence and mode numbers detection algorithm

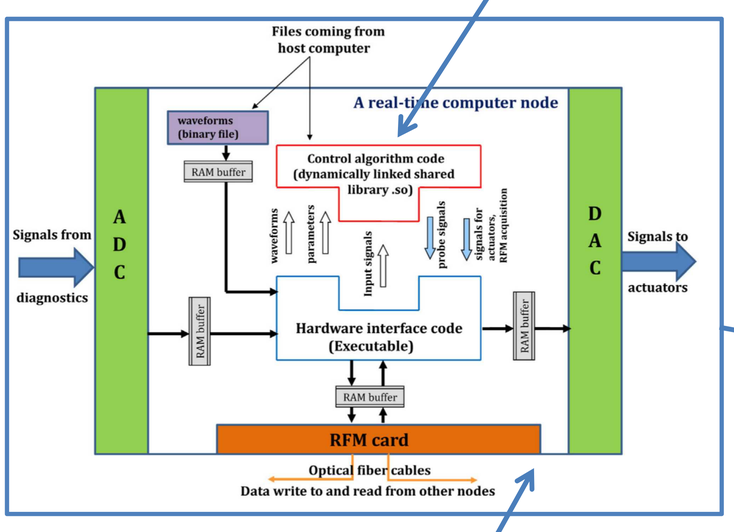
- Node 7 was programmed and tested with the SVD rt MHD analysis code described in [9].
- The algorithm uses 2 cores, here the Simulink block diagram of core 1 is reported





System/Algorithms separation line

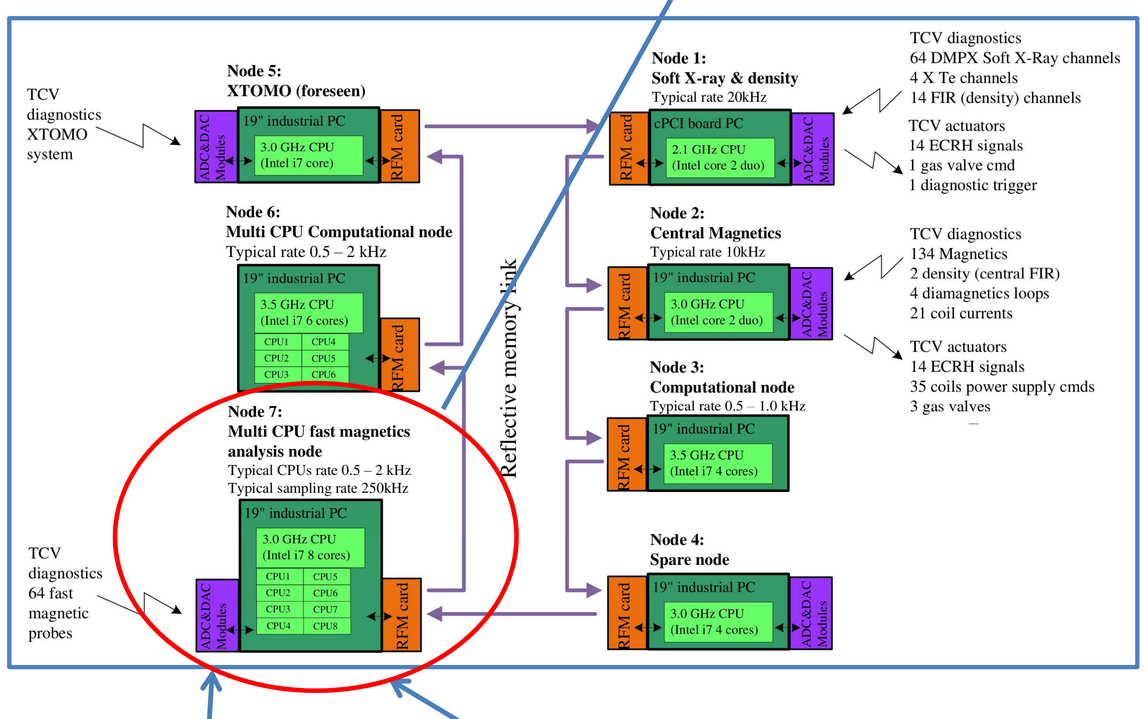
- The TCV digital control system clearly and strictly separates the environment in which algorithms are developed w.r.t. the one in which they are executed. The former is Matlab/Simulink [12,13] whilst the latter is a control system node with a dedicated C/C++ hardware interface code.

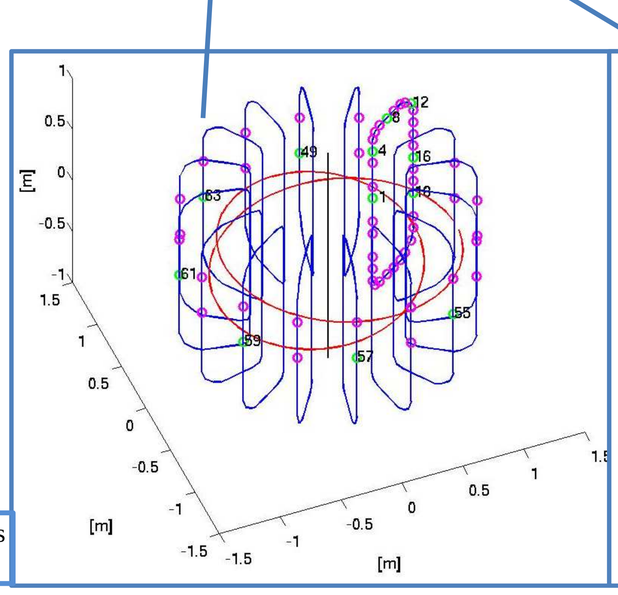


Results on TCV discharge #52219

The TCV digital distributed control system with the new node 7

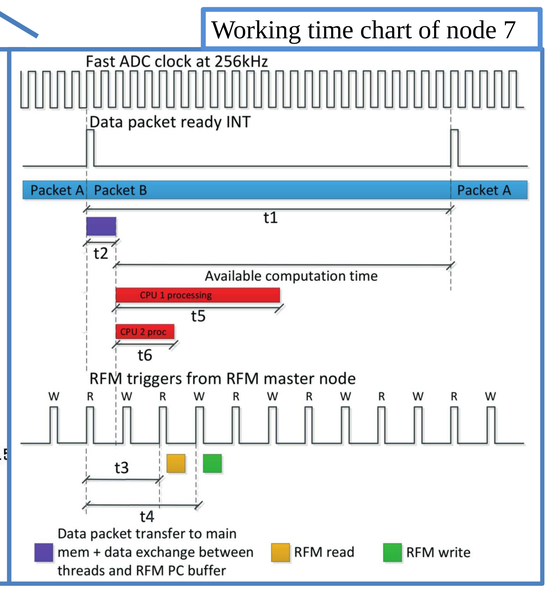
- The TCV tokamak has a fully functional digital real time control system capable of controlling almost all aspects of a plasma discharge. The system is based on a real-time sharing data network (reflective memory) of modular computer nodes, each an embedded or desktop PC which may include local ADC and/or DAC cards. [5-7, 11].
- For node 7, we adopted a packet acquisition-processing scheme where the ADCs have a double buffered data path allowing the CPUs to operate on each data packet [8]. The acquisition hardware employs an ADC subsystem with a D-TACQ ADC196 board augmented with a RTM-T rear transition module [10]. This module provides a high speed PCI-Express 1x link to the host PC, which is equipped with a recent, high-end, motherboard hosting an Intel i7-5960X 8-cores 3GHz processor. The adopted kernel is Scientific Linux 6.7 especially configured for usermode RT capabilities with a dedicated C++ hardware interface code fully compliant with the overall system architecture.
- Node 7 can acquire up to 64 channels at 256 ksps and process them in packets of variable sizes. In the presented algorithm, packet size is 256 samples per packet, granting a 1 ms long computation time to the CPUs.





TCV magnetic probes currently connected to node 7

Working time chart of node 7



Outlook

- This system has been tested during the ongoing TCV experimental campaign, providing plasma health status on the control system real time data network. It is foreseen to employ it in advanced plasma control experiments such as NTM control integration and disruption avoidance.
- We think that the approach followed in this work can be continued in the future whenever there is the need for the realtime processing of fast diagnostics with complex algorithms and to distribute results to other actors in the control system. One example on our system is the soft-x XTOMO acquisition node no. 5, which could be refurbished with an approach like that described here.

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