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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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The analysis of fast magnetic signals measured by magnetic probes installed on a tokamak vessel has been widely employed to detect and analyse a number of plasma instabilities, notably rotating tearing modes. The high frequency components of the measured signals contain information directly related to rapid changes in the plasma, for instance those generated by tearing mode magnetic islands rotating in the torus. Off-line analysis of these signals includes powerful mathematical tools such as spectrograms, principal component analysis and amplitude-phase fitting algorithms. This provides copious information on magnetic islands topology, sizes and evolution.

In this paper we describe an integration of these techniques into the TCV digital real time control system to execute advanced magnetic analysis codes during the tokamak discharge with the final goal of providing plasma health status information to decision making algorithms that can initiate actuator actions. Severe design constraints, posed by TCV's real-time environment, had to be addressed. TCV employs a distributed real time control system capable of controlling the entire plant during a discharge, consisting of commercial PCs interconnected with a self controlled high speed fiber optic digital link. Each node of the plant can house ADC and DAC boards that interact with the plant (figure 1). The goal of this paper is to integrate a new real-time magnetic coils analysis node in this system.

Main technical requirements are:

1. Simultaneous sampling of at least 32 magnetic signals at frequencies above 200 ksps.
2. Sufficient CPU time to execute a complex algorithm on the input data stream, possibly requiring multi processing capability.
3. Data interface to other nodes in the legacy control system at the speeds of the legacy system, currently 0.5-10 ksps.
4. Analysis algorithm developed in Matlab/Simulink and automatically uploaded to the analysis node, compatible with the software architecture in figure 2.

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 as described in (figure 3). The acquisition hardware employs an ADC subsystem with a D-TACQ ACQ196 board augmented with a RTM-T rear transition module. This module provides a high speed PCI-Express 1x link with the host PC, with a recent, high-end, motherboard equipped with an Intel i7-5960X 8-core 3GHz processor. The kernel is Scientific Linux 6.6 specially configured for user-mode RT capabilities with dedicated hardware interface code. The analysis algorithms are developed in Matlab/Simulink and deployed on the node in the shot preparation phase of a TCV pulse as already performed for the other nodes of the real time control system. The interface to other nodes on the control system was made identical to the legacy control system nodes.

This paper describes the first application of the calculation node, an on-line evaluation of rotating mode numbers with identification of the topology of a rotating tearing mode through an on-line singular value decomposition technique.

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