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PPR details

Statement of Work

To use the development of the plasma position reflectometry system, namely its data processing system, as a case study for the data acquisition systems of the ITER prototype fast plant system controller.

Scope

The goal of this task is to use the development of the data processing system for the ITER plasma-position reflectometry system as a test bed (or case study) for the data acquisition systems. On ITER, the plasma-position reflectometers are expected to measure the gap between the first-wall and the separatrix at four locations separated both poloidally and toroidally, known as gaps 3, 4, 5, and 6.

In the case of the equatorial channels, located in gaps 3 and 6, the data processing system is expected to be similar to the one being developed in ASDEX Upgrade. For the non-equatorial channels, located in gaps 4 and 5, the data processing needs to take into account the progressive bending of the probing beam as it propagates in the plasma as a result of the change in the curvature of the flux surfaces. This effect is most noticeable at the location of gap5 where two channels are foreseen to improve the measurement capabilities by better accommodating changes in the propagation path induced by different operation scenarios.

When processing the reflected signals one needs to deconvolute the path the beam has propagated in order to correctly convert the measured beat frequency (or group delay) to distance. In the case of the plasma-position reflectometers this implies real-time access to the equilibrium reconstruction in order to know the curvature of the magnetic surfaces and its effect in the propagation path.

The purpose of this work is to determine the necessary steps to invert the density profile in front of all gaps according to ITER restrictions, develop the corresponding data processing software and test it using the data acquisition systems being developed for ITER at IPFN.

ASDEX Upgrade Plasma Position Control Case Study

This experiment closely mimics the ITER plasma position reflectometry system in 2 of its 4 lines of sight. Both systems use O-mode propagation covering a similar density probing range (edge profile). The ASDEX Upgrade (AUG) application was demonstrated in the most demanding ITER relevant regime, Type-1 ELMy H-Mode, matching the required accuracy (1 cm) with a 10x faster measurement cycle (ITER required measurement cycle = 10 ms).

Control requirements:

• Radial Separatrix position @ 1 kHz (1ms max. latency)

Microwave coverage (O-mode propagation, homodyne detection):

• K, Ka, Q, V bands HFS/LFS => 8 ADC channels @ 40MSPS/12bits upto LFS Q band, 3x1019 m-3, used in demonstration).

Required ADC system bandwidth:

• PCIe 1.1 x8 (system in use attains a sustained ~1.27 GB/s).

RT Data Processing Algorithms hardware requirements:

• 1 Quadcore Xeon 3.0 GHz, 12MB L2 cache CPU to process HFS&LFS upto Q-band (system running on a dual quad core configuration with segregated cores devoted to the various tasks running on the system – 4 cores for RT data processing).

RT Data communication to the discharge control system:

• Gbit ethernet UDP connection, PCIe VMIC reflective memory board being tested.

Feasibility Assessment

All the acquisition/data processing components used in the ASDEX Upgrade reflectometry RT diagnostic closely match the ones in the proposed FPSC system. Namely a minimum of 8, 12 bit 40 MSPS channels (AMC boards under development) coupled to a fast data bus (at least a PCIe 2.0 x4 bus – PCIe ATCA2PSH & SDN PSH2HPC) to hand the acquired data to the processing resources (the HPC) with very low latencies (us level).

As in this experiment no data preprocessing was built into the acquisition board local FPGA, all the developed algorithms (C/C++ OMP multithreaded code using Intel IPP optimized signal processing libraries) are actually running on the Xeon multicore CPU (mainstream kernel with RT PREEMPT patches) and, hence, are easily portable to the FPSC HPC.

Conclusion: Porting this application to the proposed FPSC environment seems to be a feasible task with a minimum investment of resources.

JET reflectometry main profile Case Study

At Jet, a mixed mode (O and X-mode) reflectometry system, KG10, is used to produce full density profiles potentially reaching densities well above the pedestal. Unlike O-mode only systems (such has the AUG's and ITER's plasma position reflectometers), X-mode systems allow a density profile probing right from lowermost densities up to the inner most ones. However, in order to calculate the X-mode density profile, the knowledge of the radial magnetic profile is required.

In the 2012-2013 period, IPFN will propose to produce an assessment on the possibility of producing on JET real-time (RT) full density profiles. This capability is particularly important in the preparation of novel feedback control schemes for future advanced plasma scenarios. Furthermore, such an application is being proposed for the ITER main plasma reflectometer by the American & Russian teams (P. Varela).

As JET is the most ITER relevant machine and possesses a modern high performance reflectometer, it seems the ideal environment in which to test a full implementation of a working FPSC.

This proposal benefits from the following factors:

• IPFN as tight ties to JET CODAC & Control teams, and experience in the design, deployment and operational exploitation of ATCA based control and data acquisition systems.

• IPFN microwave team participated in the design and construction of the KG10 main profile reflectometer, and produced on AUG a demonstration of RT position control using reflectometry.

• JET KG10 diagnostic is prepared to allow the test of a RT system setup (similar to the FPSC) working in tandem with the existing systems without major hardware changes/upgrades (Meneses).

Limitations:

• Presently the Microwave group has no experience in the RT inversion of X-mode profiles. Although the standard processing and inversion procedures is reasonably mastered at this time at JET, RT algorithms need to be developed and tested for this application.

Potential synergies and future work:

• The experience and know-how obtained in such a project can be directly ported to an equally ITER relevant machine such as AUG, where a hardware refurbishment is planned to revive AUG's profile X-mode reflectometers. Due to the characteristics of the AUG experiment, a feedback control demonstration using the actual FPSC could perhaps be more easily achievable in the longer run.

Perspectives on the use of syntethic diagnostics

(Filipe Silva, Rui Coelho)

Status

Short term perspectives

Potential contributions to the project

Requirement specification

Note: for an introduction to requirements specifications please elaboration read this tutorial

Tasks

The high-level tasks to be performed are:

1. Using available ITER data simulate as accurately as possible the propagation of the probing beam for the non-equatorial channels and use these simulations to develop the data processing algorithms capable of extracting the correct propagation path for a given equilibrium reconstruction and launching angle.

2. For ITER reference scenarios simulate the raw data to be expected at each location and use the previously developed algorithms to correctly invert the density profile and provide the gap estimation in real-time in compliance with ITER restrictions.

3. Test and optimize the developed tools using the data acquisition systems being developed for ITER by IPFN.

4. Implementation in case study machines (TBD)

Project management

Note: To understand the IPFN projects lifecycle pelase read the tutorial