ASDEX Upgrade
Letter

No. 8/March 2006

Foreword

With the recent site decision ITER has entered the crucial phase leading to its construction and operation. The whole fusion community feels the responsibility of a big scientific and technological challenge, whose outcome may strongly influence the efforts of providing a sustainable energy future for mankind. The European fusion programme is at the forefront of worldwide research, and ASDEX Upgrade is a key player.

Understanding, control, education and synergy are four important keywords for the success of the fusion enterprise. At ASDEX Upgrade we endeavor to keep them as guidelines, as illustrated by the contributions in this issue. The new fast ion loss diagnostic is a successful tool to understand the physics of suprathermal particles – think for example of fusion born particles – whose behaviour will deeply affect the dynamics and the efficiency of ITER and in general of a fusion reactor.

Since the times of the magnetic core rope memory used to store programmes in the Apollo 11 guidance computer, control technology has made gigantic steps. The new ASDEX Upgrade plasma control system provides a working example of a "state of the art" tool for safe and user-friendly guidance of a fusion device.

A successful story is always made by people: that is why at ASDEX Upgrade we care about students, who are the future of fusion and who find here a dynamic, high-quality and international environment for their education. Moreover, this is why our programme has been opened to international collaborators, who not only participate with their proposals, but are also integrated into management of the experiment.

With the enthusiasm arising from my exciting experience as Task Force Leader and from the interaction with an excellent team, I wish a successful 2006 experimental campaign!

P. Martin

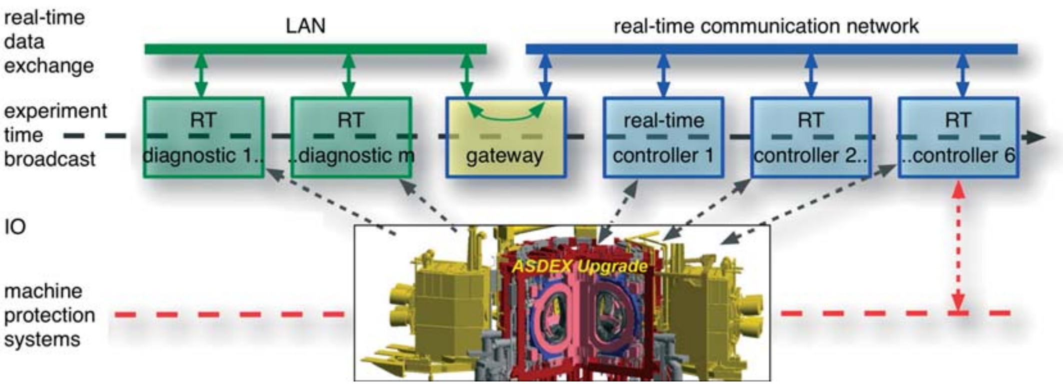

Fig. 1: Architecture of the new ASDEX Upgrade control system.

New Plasma Control System at ASDEX Upgrade

ASDEX Upgrade (AUG) started operation in 1990 with the first fully digital plasma control based on clusters of transputer processors. It influenced progress in vertical plasma stabilization and shape control with distant coils, performance optimization and disruption mitigation. Today, transputer technology is outdated and has vanished from the market. In addition, on the way to ITER, more advanced control is considered to be a key technology to produce and sustain fusion plasmas and reduce machine stress. In order to demonstrate such improved technology a new distributed real-time (RT) control and data acquisition system for AUG was designed and implemented. Thereby, individual units transparently exchange RT discharge data. Depending on input and computing requirements units can be added. By using industrial components the new system benefits directly from IT progress. Presently it consists of 6 controller PCs and a growing number of RT diagnostic nodes, working under SOLARIS, LINUX and VxWorks (see fig.1). RT networks exist for communication (shared memory) and absolute experimental time.

RT processes fall into three functional groups. Two of these handle device specific sensor input and actuator command output. Between these, a third – virtual physics – group performs all device-independent plasma feedback and monitoring (see fig. 2).

The flexible system design allows enhanced control functionality:

- More diagnostic input:
Now RT diagnostics (or actuators) can be connected immediately via the RT network or via slower but cheaper LAN to a gateway on the RT network. Old serial links to more than 20 diagnostics have been upgraded both in channel number and speed. Via the RT network diagnostics receive pulse file, plasma or device state info, and can compute RT data for control and monitoring, or adjust data acquisition settings.

- Improved actuator handling:
Sophisticated operation limits can be established (e.g. NBI shine-through with density mapping), priorities are handled and FB is adjusted to actuator availability.

- Flexible process adaptation:
The generic approach permits processes to be modified via configuration (RT data and parameters to be processed, RT data to be produced) rather than encoding. This helps to adapt FB or monitoring, or switch RT input on the fly (e.g. to replace failed sensor data or badly evaluated data).

- More, and enhanced control processes:
With more input data and increased processor power, more elaborate algorithms can be run and plasma parameters can be calculated with higher precision. In particular, the FB controlled stabilization of NTMs with the upgraded ECRH system will rely on this improvement.

- Improved discharge sequencing:
RT execution conditions can be ►

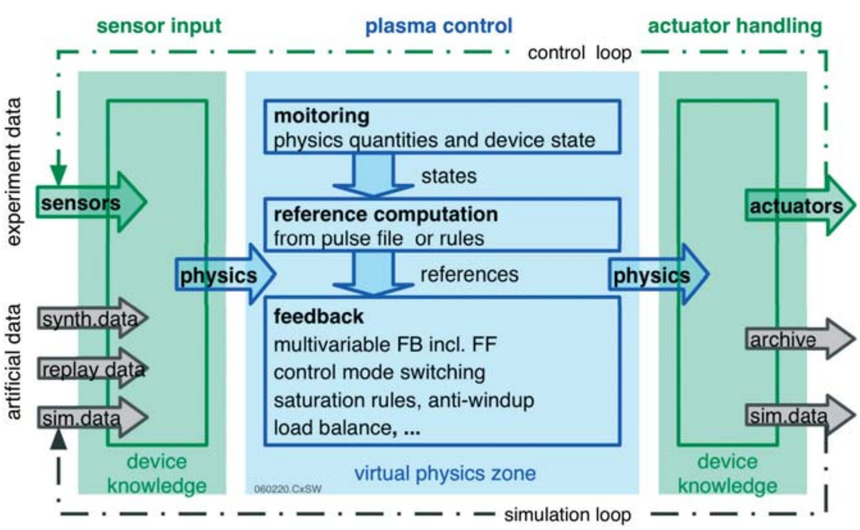

Fig. 2: Overview of software structure

Highlight
from a recent ASDEX Upgrade experiment

Observations of MHD Induced Fast Ion Losses

In fusion plasma devices suprathermal ions generated by heating systems and fusion born α particles must be well confined, until they have transferred their energy to the plasma. Significant loss of these ions may drastically reduce the heating efficiency and, in addition, may cause damage to plasma facing components in the vacuum vessel, if it is sufficiently intense and localised. A detailed knowledge of the underlying physics in particular in the presence of MHD instabilities is of crucial importance, since they can lead to an enhancement of the outwards fast ion radial drift.

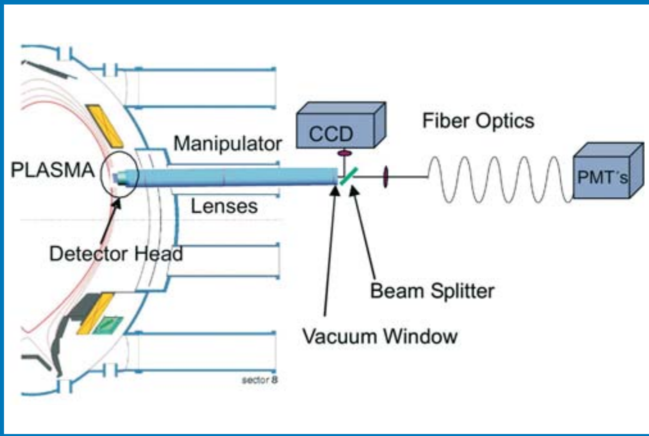

Fig. 3: Schematic of the fast ion loss diagnostic.

Therefore, a new scintillator based detector for fast ion losses (FIL) has been put into operation in the last experimental campaign (see fig. 3). The design is based on similar diagnostics that have been operated in TFTR and W7-AS. Recently, the IPP expertise in this area has also been used to install such a diagnostic in JET. The fast ion loss detector acts as a magnetic spectrometer, dispersing fast ions onto a scintillator, with the hitting point depending on their gyroradius (energy) and pitch angle (angle between ion velocity and magnetic field line). The emitted light pattern allows the particle identification in the phase space with a high time resolution. The major new development for the diagnostic used on ASDEX Upgrade is the use of a very fast scintillator material that allows sampling rates up to 1 MHz, adequate to study the time resolved interaction between MHD modes and fast particles.

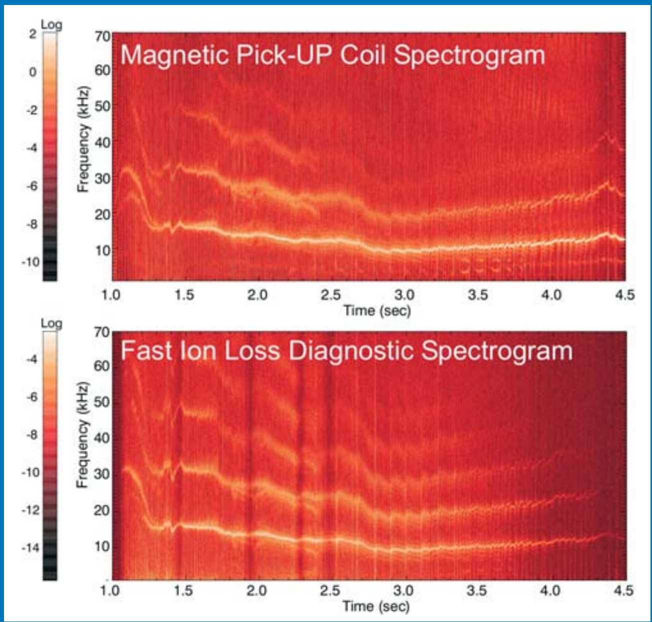

Fig 4: Spectrograms of a magnetic pick-up coil (top) and of one fast ion losses diagnostic channel (bottom). Fast ion losses are well correlated with a 3/2 NTM and its harmonics are clearly visible.

Fast ion losses were observed in the presence of different kinds of MHD instabilities: (i) Time resolved ELM induced fast ion losses have been directly observed. They show a complex behaviour of a great variety, depending on the ELM substructure. (ii) Fast ion losses could be measured in the presence of ICRH triggered Alfvén Eigenmodes. Generally these losses coincide in frequency and amplitude modulation with the Mirnov pick up coil signals. (iii) Finally, fast ions ejected by NTMs have been detected (see fig. 4). Analysis of the underlying physics mechanism is under way.

The results of just one campaign of operation revealed the high diagnostic potential of this method. It opens new ways towards a better understanding of the fast ion physics and therefore will help to predict the behaviour of fast ions in the presence of MHD instabilities for ITER.

modified easily to branch through pulse file segments, depending on the actual plasma and device state. Even the cycle time can be modified.

- In-situ tests with artificial data:
Part of or all RT sensor data can be replaced by a free mix of synthetic (i.e. edited references rather than input data), replayed (i.e. previous discharge's input data rather than actual experiment input) or simulated data. This is used to verify system response (e.g. system check on software modification) or to support controller development.

- Speed-up:
The system facilitates the continuous modernization of IO, processors and RT network. During commissioning, cycle time was reduced from 4ms to 1.6ms, with an aim at the actuators' 1ms response limit.

Although complex, the new control works reliably. Application processes monitor numerous machine critical states, propagate alarms and execute comprehensive machine protection functions, integrated with other protection systems, to guarantee safe reaction and low overall stress.

Once advanced user interfaces for experiment automation, pulse file - editing and post-discharge analysis are finalized, it will be up to the ASDEX Upgrade community to develop new control algorithms and to explore the control system's wealth of novel features to its full extent.

Start of the 2006 experimental campaign

The 2005 shutdown was used to proceed with the AUG tungsten programme towards a full tungsten machine. Tungsten coated graphite tiles have been installed on 85% of the inner wall. Only the lower divertor is still carbon. In the 2006 shutdown (Aug. - Dec. 2006) these tiles will also be replaced by tungsten coated ones. Other major hardware upgrades, which will become available in 2006:

- Extension of ECRH – In March a new 2-frequency gyrotron will start to couple power to the plasma. On the teststand 600 and 800 kW were achieved for 10 seconds at 105 and 140 GHz, respectively. Another gyrotron with similar specification and the option to operate at two additional frequencies is supposed to be delivered during the summer break.

- High repetition pellet injector (blower gun, 140 Hz) optimized for ELM pace making. The pellet track from the LFS with a variable angle of injection (approximately tangential to the last closed flux surface) will allow the study of ELM pacing almost without any plasma fuelling. Installation of the new injector, which was developed together with the Hungarian Association HAS, will be finished in March.

The involvement of European Associations in the AUG programme is maintained at the high level of previous years. Meanwhile the annual 'Call for Participation' in forthcoming AUG campaigns is a routinely performed procedure to take on board scientific ideas from almost everywhere in Europe. As a response to the call for 2006 experiments, non-IPP scientists submitted approximately 60 out of 160 proposals.

After prioritizing and clustering, a coherent 2006 AUG programme was established and approved by the AUG Programme Committee (8 IPP and 11 external members) at the end of November 2005.

No major technical problem occurred during the AUG restart in December 2005. The start of the experimental programme in January 2006 proceeded well. Although it quickly became obvious that the operation of the machine with higher tungsten coverage is more challenging than in previous campaigns. Not only is the operation of specific scenarios more difficult, also new and unexpected effects occurred. In comparison with a carbon surface the latter are mainly related to a substantially different ability of tungsten to store and release noble gases, which are used at AUG for disruption mitigation, glow discharge cleaning and for divertor temperature control. In such a situation of rising operational demands a more flexible discharge control is required. With the new possibilities of our new control system we have the tool to master these challenges.

ASDEX Upgrade Letter
published by
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