New Signal Processing Methods and Information Technologies for the Real Time Control of JET Reactor Relevant Plasmas

A.Murari [1], J. Vega[2], D. Mazon[3] and JET-EFDA Contributors*

JET-EFDA, Culham Science Centre, OX14 3DB, Abingdon, UK

[1] Consorzio RFX-Associazione EURATOM ENEA per la Fusione, I-35127 Padova, Italy
[2] Asociación EURATOM-CIEMAT para Fusión, CIEMAT, Madrid, Spain
[3] Association EURATOM-CEA, CEA Cadarache, 13108 Saint-Paul-lez-Durance, France
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Corresponding author:andrea.murari@jet.efda.org

To improve their reactor relevance, the configurations of present day Tokamak plasmas are very sophisticated and typically require operation at the boundary of the safe region in the parameter space, a fact that tends to make the configurations more unstable and arduous to control. These difficulties are compounded by the increased amount of data to be handled: in JET a maximum of more than half a Terabyte of data per day has been acquired in a single day of operation and a good fraction of it would be useful for feedback purposes. To face these challenges, in the last years significant efforts have been devoted on JET to the development of new signal processing methods and technologies to both improve the performance of the plasmas and to increase the operational safety.

Probably the most important line of research is devoted to determining the plasma equilibrium in real time. Two codes, implementing alternative approaches, have already been validated on JET. The first one, called EQUINOX, is based on the solution of the traditional Grad Shafranov equation. The other is purely experimental and performs only probabilistic calculations, using Bayesian statistics, without any assumption about the plasma behaviour. These two codes require computational times fully compatible with control requirements (the Bayesian approach can produce a equilibrium in a few ms) and they therefore open new prospects to the potential of feedback control (from current profile to ITBs).

One of the main threats to Tokamak machines is still constituted by disruptions. A new predictor, based on an original use of Support Vector Machine methods, has been developed for JET. It has a success rate of almost 95 % on the campaigns in which it has been trained and its performances remain very high, above 85 %, even for discharges performed years after the last one use for the training. Various forms of anomaly detection techniques are also being developed with the long term goal of providing a sort of automatic surveillance of JET operation.

Cameras, both infrared and visible, have become much more widespread in fusion research devices in the last decade. The image processing to be performed is quite sophisticated and requires advanced techniques. The implementation of the Cellular Nonlinear Network paradigm on FPGAs allows the detection of hot spots in the frames of JET wide angle camera with a frequency of 100 Hz and a practically 100% of success.

For all the aforementioned techniques, specific examples of applications to JET will be provided. The need to identify a validated and optimised portfolio of solutions for the next generation of machines, like ITER, where many problems are expected to be significantly more severe, will also be discussed.