Real Time data acquisition system for control and continuous acquisition in Tore Supra

2003 IEEE Real Time Conference

F. Leroux, B. Guillerminet, D. Moulin, F. Saint-Laurent
Association Euratom-CEA, DRFC, Cadarache.
13108 Saint Paul lez Durance Cedex, France

***Abstract*—The Tore Supra data acquisition system has been upgraded during the Tore Supra 2000/2001 shutdown to fulfill the request to run long duration discharges. The Tore Supra Tokamak is a large and complex device and needs to share information from different systems and to record data not only during plasma discharges but also between discharges (calorimetry, vacuum, magnetic field...). The data acquisition system for infrared cameras, new plasma control and continuous data acquisition are major upgrades. The experimental campaign from September 2001 to November 2002 provides the first results for these upgrades.**

I. INTRODUCTION

During the experimental campaign from September 2001 to November 2002, 4 minute plasma discharges have been performed with a world record of injected and extracted energy of 750 MJ. First results were obtained using the new continuous data system and new plasma control.

In the first part of this paper we will talk about two new real time controls of plasma integrated into the shared memory network:

- The limitation of injected power of the lower hybrid heating and the ion frequency heating by the level of copper and iron detected by the duochromater spectrometer.
- The control of gas injection by the radiated power measured by the bolometers.

In the second part, the results of continuous data acquisition on two of the data acquisition units will be described :

- The calorimetry diagnostic.
- The fast discharge controller for toroïdal security.

In a third part the evolutions of the data acquisition system and the real time plasma control will be approached.

Note that the data acquisition system for infrared cameras is not covered in this paper [1].

F. Leroux is with the Commissariat à l'énergie atomique, DRFC, Cadarache, 13108 Saint paul lez Durance cedex FRANCE (telephone: +33-4-42-25-46-55, e-mail: fabrice leroux@cea fr)

II. REAL TIME PLASMA CONTROL

The real time plasma control system is completely integrated into the Tore Supra data acquisition system [2] (fig. 1). Acquisition on input boards, control and application of the consign are all performed by the same VME acquisition unit using PowerPC processors monitored by a real time UNIX like OS, LynxOS™.

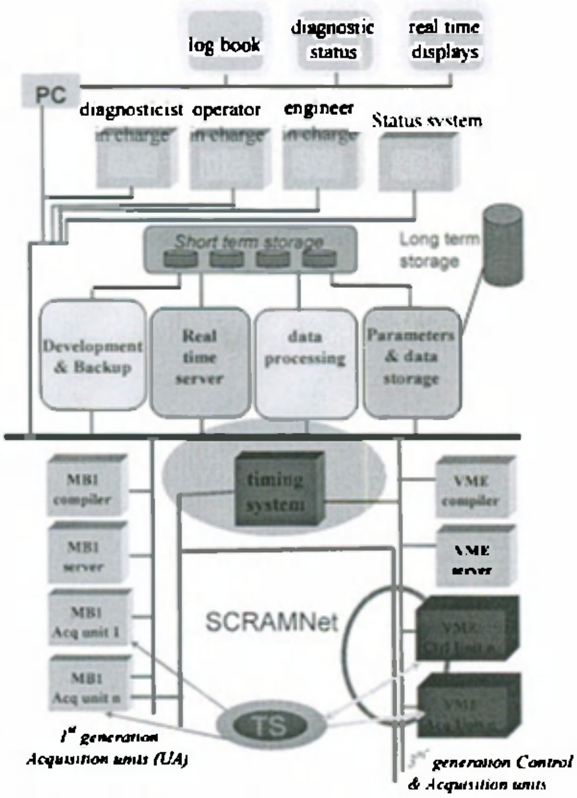

Figure 1: The data acquisition system of Tore Supra

A VME acquisition unit is equipped with two processors, each in charge of a specific function. The first is for communication with the real time server in order to synchronise the acquisition and the control with the timing of the discharge, to transmit raw and calculated data to archive them as a standard diagnostic unit. The second unit is for acquisition on input boards, calculation from input data, using control loops from a specific algorithm and the application of these calculated voltages to the different elements of the subsystem it manages. Intercommunication between the processors is fulfilled through shared memory by the VME bus (fig. 2). The first processor receives data from flip-flop buffer filled by the second processor via the shared memory. The application program in the first processor is made up of several tasks such as the timing chronology of the plasma discharge, the sending of data, the management of the events. The second processor runs a single task to reach the real time. Data acquired and calculated by the second processor are also written into the shared memory network for other control units.

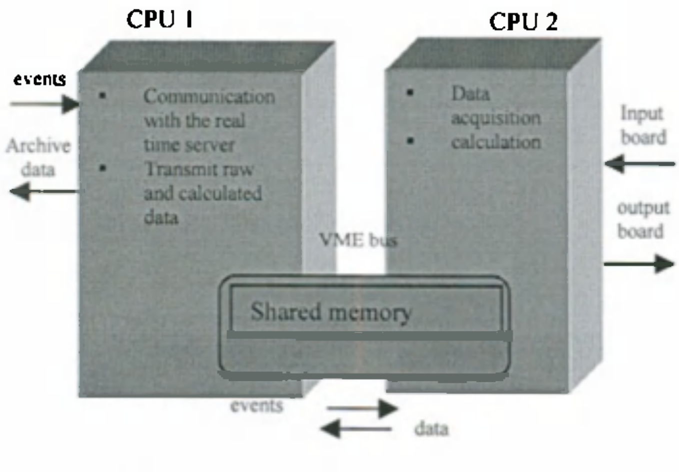

Figure 2: Intercommunication between processors

1) Shared memory network

The shared memory network is implemented via SCRAMNet® boards from SYSTRAN Corporation. Each processor on the network has access to its own local copy of shared memory that is updated over a high-speed, serial-ring network. Any data written into SCRAMNet® are automatically sent to the same shared-memory location in all nodes of the network. It is also referred to as a replicated shared memory. Data are transmitted at a rate of 150 Mhz over dual fibre optic cables. The protocol is a register-insertion methodology and not a token ring. There is no master node and all nodes have same priority. Every computer on the network has a constantly updated local copy of all global data which is passed to all the network computers. Each board implemented in each unit is declared as a node on the network and each node receives a number. Therefore the use is very easy. The whole memory (512 Kbytes) has been divided in pages of 32 Kbytes. Each page is devoted to one node, consequently for each unit. Only the unit to which it belongs is allowed to write in. But all the pages can be read by all the processors of the network.

In 2002, two units have been added in the real time control system. Figure 3 shows the global control system.

2) DDUO unit for copper and iron security

The DDUO acquisition unit is a duochromater spectrometer. It provides, in the shared memory network, the level of copper and iron radiation from the plasma every 8 ms. This permits to the acquisition unit of the lower hybrid heating (DHYB) and the ion frequency heating (DFCI) to limit the injected power in real time. A comparison is performed in the acquisition units DHYB and DFCI to an preset percentage. If the value provided by DDUO exceeds this threshold, the power is gradually reduced by 25%, then increased again.

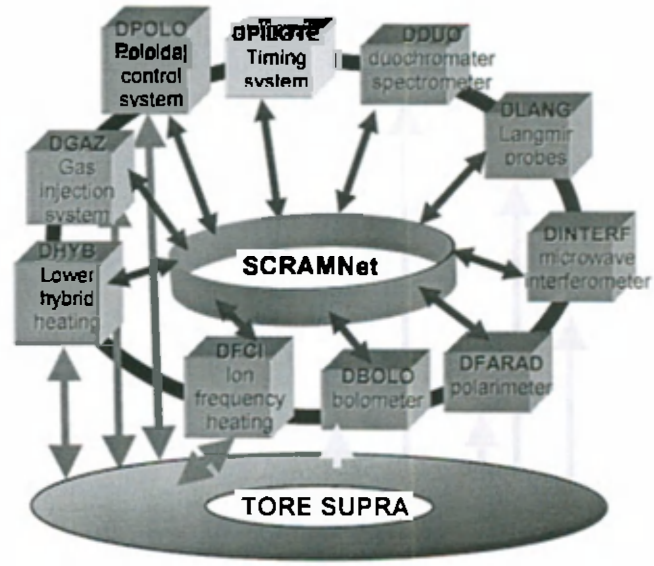

Figure 3: Global control system

3) DBOLO unit for control of gas injection

The radiated power delivered by the bolometers (DBOLO acquisition unit) is provided every 1 ms and stored in the shared memory network. The DGAZ acquisition unit compares the radiated power and the total power ratio with a set-point. The gas input is reduced when the set-point is exceeded .

III. Continuous data acquisition

The data acquisition system has been redesigned to conform to the long pulse requirements [3]. This upgrade allows not just the long pulse duration but also continuous operation. Continuous data acquisition makes it possible to supervise some values which are not stable during a long discharge.

The supervision and storage tasks and also the timing system must be always running. The acquisition rate is driven by incoming events, which are generated by other diagnostics, or by the timing system. A diagnostic can start at any time but must fit into the overall event strategy and thus cannot rely on a fixed sequence of events. In continuous operation mode, the time must be recorded absolutely rather than relative to an event. Hence the continuous data look like our usual pulse raw data with the same internal format, but with a time relative to midnight. The data acquisition is started by the launch of the program. It accesses the database, downloads the relevant on-line parameters and after the set-up, launches the polling and acquisition tasks. The acquisition rate is then changed on a timing event receipt or by a dedicated message such as 'start of pulse', 'end of day', etc. At these messages, the tasks download and update their parameters. In contrast to the standard acquisition system, the data taking goes on even after the end of the pulse with the same rate until a new event or message. Figure 4 shows a summarized scheme of the different stages.

The absolute time is taken from the CPU time because the acquisition units do not have a universal time system. The CPU time is not accurate enough for fast data but is sufficient for slow variation physical values. All the data are corrected with the 'start of acquisition' absolute time corrected by the clock cycles from the start. When the acquisition unit receives the 'start of pulse' event, it uses it to time stamp all the subsequent data. The change of any parameters of our acquisition boards implies a complete stop of acquisition, and loss of data during the stopped period.

1) The calorimetry diagnostic

The calorimetry diagnostic permits a survey of both the cooling water temperatures from the plasma components, and the bolometer plasma radiation temperatures.

It acquires 224 channels with a period of 250ms and 1s during the night. The volume of the data is of approximately 20 Mo per day.

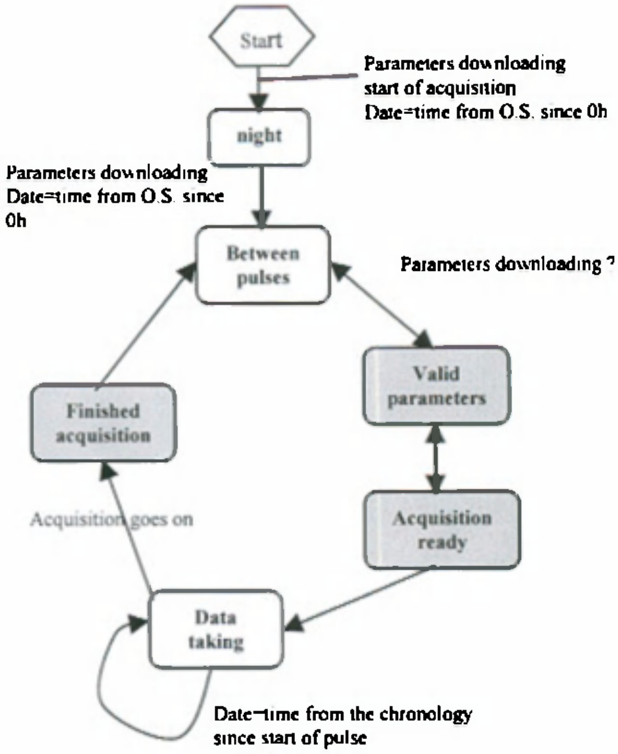

Figure 4: Acquisition stage

2) The fast discharge controller diagnostic for toroïdal security

This controller became, in 2002, a standard acquisition unit. Previously, the unit only made up of one processor, was responsible for collecting the data of toroïdal system when a fast discharge occurred. These data, stored in files, were analyzed after the end of the discharge. The unit is now a continuous acquisition data unit to make it possible not only to improve data access but to be able to carry out continue monitoring of the toroidal system. This safety unit is now equipped with two processors. The application of the first processor is multitask, collecting continuous data and managing events. There is a single real time task in the second processor. It is running the old application enriched by data transmission to the first CPU. Three acquisition strategies are used:

- A period of 128ms during the plasma discharge.
- A period of 1 second between the plasma discharge.
- A period of 10 seconds during the night.

IV. Future plans

1) Data acquisition system

The Tore Supra data acquisition system will be upgraded in 2003 to manage larger amount of data and to keep up with the data flow increase. Currently, the acquisition system is able to collect, analyze and display the real-time data. This acquisition is realized by several specific software tasks running on a real-time VME architecture under the LynxOS™ operating system. The data are acquired and transformed by a VME acquisition unit during the plasma discharge and then, they are sent to a UNIX cluster which monitors and stores them. In 2003, some diagnostics want to trigger their data acquisition many times during the plasma discharge, with a very short time delay between each of them.

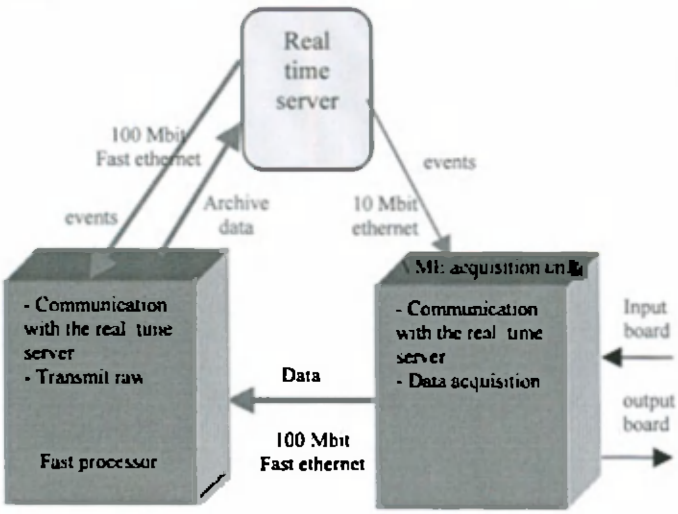

Figure 5: Future acquisition data system

Due to their real-time features, the acquisition units are not able to transform and send data (up to 35 M measurements) every 250ms.

To fulfill these new requests our acquisition system will be distributed among a few computers, one in charge of the raw data and an other to transform them (fig. 5). These computers will be based on faster processors and networks but all of them will still be running during the pulse.

2) Real time plasma control

Four acquisition units were added into the network for the first half of the campaign year 2003:

- the electronic cyclotron heating (DFCE) unit will have the same type of control as DFCI and DHYB unit.
- the ECE heterodyne radiometer and the X spectrometer (DSPX) will provide measurements for the profile control.
- Infrared security SCAMIR for the plasma facing component security.
- An acquisition unit dedicated to advanced plasma control will be added. This acquisition unit, more powerful on calculations level, will be in charge of profile-control calculations and will deliver the feedback parameters to the other relevant acquisition units, which will apply them.

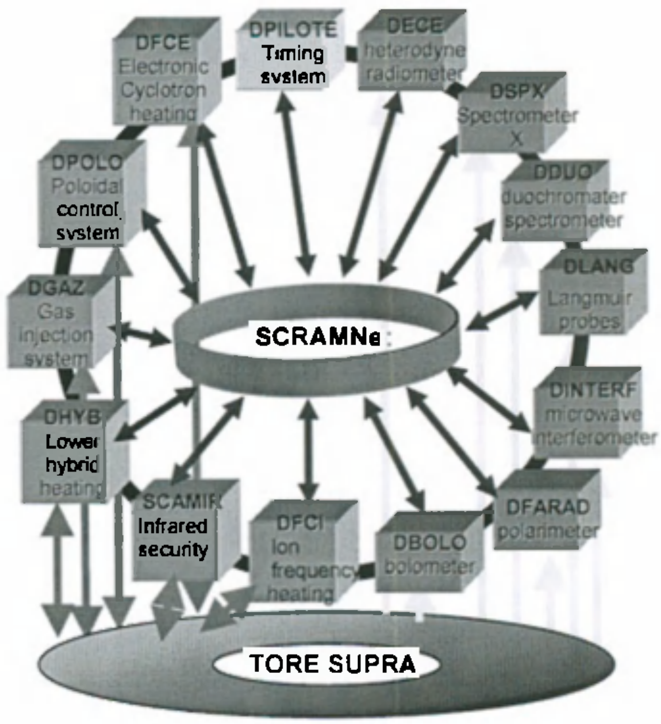

Figure 6: Future real time control system

V. Acknowledgements

The authors express their sincere thanks to all the members of the computer and electronic groups

VI. References

[1] D. Moulin, "The data acquisition and interlock system for Tore Supra infrared imaging" *Soft 2002, Helsinki*

[2] D. Moulin, "The real time plasma control system of Tore Supra" *iaea 1997, Garching*

[3] B. Guillerminet, "Tore Supra continuous acquisition system" *Fusion Engineering and Design 60 (2002) 427-434*