THE CONTROL OF GENEPI, A GENERATOR OF PULSED INTENSE NEUTRONS

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Abstract

GENEPI is a generator of pulsed intense neutrons constructed for one of the experiments of the GEDEON project, the purpose of which is to investigate the properties of accelerator driven reactors. GENEPI is at present in use at the ISN for preliminary measurements, and will be installed for the injection of pulsed neutrons into the core of a small scale nuclear reactor.

Part of the accelerator is housed in a HV cage. The relative lack of space available and the HV requirement lead us to adopt a solution based on PC104 single board computers. Acquisition interface cards were developed at the ISN Grenoble.

1 GENEPI

Accelerator driven or "hybrid" nuclear reactors present a hope for more secure, and more efficient production of electricity. They also could be used to incinerate stockpiles of nuclear waste [1].

GENEPI (Génerateur de Neutrons Pulsé Intense) is an accelerator designed for the study of the neutronic properties of accelerator driven nuclear reactors [2]. The neutrons are produced by the interception of a beam of pulsed intense deuterium ions (D+) by a tritium target. It is at present in operation at the ISN in a stand-alone configuration. Early in 2000 the accelerator will be moved to the French Atomic Energy research center CEA-Cadarache and the tritium target will be installed in the core of the MASURCA research reactor.

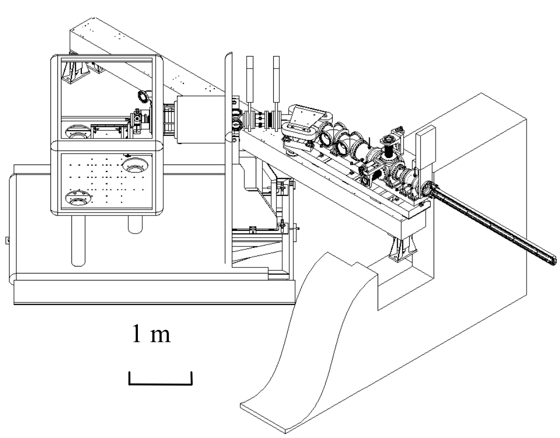

Figure 1 The structure of GENEPI

Figure 1 shows the general structure of GENEPI : The accelerator is of classic design, a pulsed beam of deutons of 250 keV is produced in a duoplasmatron source, on the left of the figure. The source and its auxiliaries are placed in a metallic high tension cage which is raised to a potential of 250 kV. The extraction and focusing electrodes are also placed in the HT cage, together with their power supplies. The ions are then focused, sorted by passage in a dipole, and transported to the tritium target, where neutrons of 14 MeV are produced. On the right of the figure can be seen the wall of the reactor.

2 THE CONTROLS OF GENEPI

2.1 General Architecture

The equipment to be controlled consists mainly of power supplies. There are also some elements of vacuum, and some beam diagnostics. No security aspects are treated.

The main characteristic of GENEPI from the point of view of the controls, is the necessity to control a certain number of elements within a confined space, under the constraints of the high voltage.

The basic architecture of the control system is a TCP/IP network of PC104 mono PC cards, with the man machine interface running on a Windows NT platform. The equipment is interfaced to the PC104 bus ADC/DAC and logic I/O interfaces. The PC104 cards are physically small, and available from many sources for a low cost. We had previously used this standard for an application on the accelerator SARA[3].

For the acquisition of beam diagnostic currents we have re-used an in-house board developed for SARA.

The control of the generation of pulses is achieved by in-house developed hardware, which will be interfaced to the control system synoptic. The monitoring of the pulse shape uses an oscilloscope, which can also be interfaced to the synoptic so as to correlate the pulse characteristics with the setting parameters.

2.2 Particularities of GENEPI

As mentioned above the main problem with GENEPI is to ensure that the control system is not perturbed by the dielectric breakdown or sparking which may result from close proximity to high tension.

Since GENEPI will be installed as an injector to a nuclear reactor the whole project has been subject to nuclear security constraints. However these constraints have had minimal effect on the control system.

3 DETAILS OF THE HARDWARE

3.1 The PC104 cards

The PC104 cards we use are MOPS LCD3 from JUMPtec Industrielle Computertechnic. They have the following main characteristics :

- 80386 SX 33 MHz.
- 2 MO RAM
- "FLASH" silicon disk 770 kO
- Interface VGA, mouse, keyboard, Ethernet RJ45
- 2 serial ports, 1 parallel port,
- dimensions 90 mm × 96 mm.

3.2 The Interfaces

No commercially available interface was found to provide the required protection from the very high voltages, and also to ensure the required control over the rest state and the initial conditions of the interface. The accelerator must continue to function if one of the PC104 controllers fails, and also during a reboot. It was decides to specially develop interfaces for this application, building on our previous experience with this standard.

Each PC104 is provided with an interface containing 4 PPI (Programmable Peripheral Interfaces) 82C55A circuits. These circuits can be configured individually to be analogic or logic input or output. To each PPI can be connected either a bi-directional opto-insulated logic card or a 12 bit ADC/DAC card with galvanic insulation.

In the confined space of the HV cage we have been forced to group the equipment on the controllers as much as possible, and this solution has given us great flexibility.

3.3 Network

The PC104 cards are connected to the network by twisted pairs via a hub, for both the part at ground potential, and the part within the HV cage. The two parts are connected by fiber optic cables.

4 SOFTWARE ASPECTS

4.1 The User Interface

The user interface program is written in Lab Windows CVI v5.0.1., from National Instruments, on a Windows NT4.0 platform. Although we use no acquisition directly on the WinNT PC, and thus did not benefit from one of the nicest features of this software package, our previous experience with it convinced us that it would be worthwhile simply for the speed of production of a user interface.

CVI contains many libraries and sample applications for acquisition, network, and user interface programming, and benefits also from excellent technical support and a very active user forum.

The user interface reads all configuration details of the equipment in an EXCEL file, using ActiveX commands. It acts as a TCP client to send commands to the PC104 equipment controllers, and as a UDP server to receive regular status messages from the equipment.

Data logging was not part of the initial user requirements, but a printed report of the status of the machine can be produced.

The user interface consists of

- A configuration panel, which allows the user to change the values of ramp constants, and default set values. After a change the configuration files for the PC104 equipment controllers are generated automatically by the user interface program, and a command can be sent to the controller to restart using the new values.
- The main synoptic panel, which contains all the status data of the elements. The commands are available on floating detail panels, grouped for convenient machine operation.
- A panel to report errors, in which errors in the equipment reported by the controllers, or errors of communication detected by the synoptic are listed.

The user interface program is multi-threaded. The main thread is reserved for user interaction. A very busy background thread checks for UDP messages arriving from the equipment. (The sending of a TCP command generates a CVI managed thread). Printing a report creates a temporary printing work thread. Error reporting also requires a separate thread.

4.2 The PC104 acquisition

We chose to use DOS 6.21, which is simple, compact and reliable, and which we know well.

When a PC104 boots it must access the hard disk of the Windows NT machine in order to load the Ethernet software, read its program and configuration file. This is achieved using the Microsoft NETBEUI protocol.

DOS has of course, no native TCP/IP support. We used the package PC/TCP for DOS from FTP software.. This software in fact provides DOS emulation of the WINSOCK library. This meant that the sockets programming for the PC104 cards was practically identical to the Windows side. The PC104 send regular reports of their status to the synoptic using UDP broadcast messages. They are TCP servers, listening permanently for user commands.

The programs for the PC104 were developed using the Borland C++ compiler on Win NT. A base class takes care of the most of the logic I/O (impulsion). Derived classes add the analogic parts, and also overload certain methods to manage the valves, and the rest of the logic I/O (maintained). Each instance can manage ON/OFF and RESET commands, read three status bits, send a DAC value and read an ADC.

Each program is a simple loop of acquisition, polling for the arrival of a command, and if necessary, sending a status message to the synoptic.

If for any reason the acquisition program cannot start, a built in hardware watchdog resets the PC104 by lowering the POWER ON signal. As the subsequent reboot sends an impulsion to the interfaces it perturbs the DAC value sent to the equipment. It was necessary to write a separate "resident" watchdog program which runs in the background to check the acquisition loop is running. If it is not, a warm reboot is triggered, and the acquisition program restarts cleanly.

4.3 Treatment of Errors

Two levels of error can be generated; "severe" which mean that beam production is probably halted, and "normal" errors, for example temporary communication breakdown with a controller. These errors are taken out of the list after a certain time and will disappear if the error condition is no longer true, or be re-posted. The operator can choose to acknowledge the error with a double click, in which case the error will remain in the error list. The operator can also choose to erase all the error list. In this way the error list does not grow infinitely, but could be used to study a particular error condition.

4.4 Synoptic Update Frequency

The limiting factor for updating the synoptic panels is the rate at which the Win NT system can reception the UDP broadcast messages, and get the information onto the screen. It seems that the CVI program and Win NT cannot receive and display more than around 70 UDP messages per second, but it is difficult to extrapolate laboratory measurements to the real case.

Obviously, the update frequency of a diagnostic current must be greater than that of for example a vacuum pump status. In our system several parameters enable us to fine-tune the different update frequencies.

The PC104 will send a message:

- if a command has been received,
- if a value or status has changed and PC104MinTime has passed since the last message sent,
- if no message has been sent since PC104MaxTime.

For a slow moving equipment, such as a valve, PC104MinTime and PC104MaxTime can be the same, and set to a value between 0.5 and 1 s.

For a diagnostic current however, the requirements for machine operation are to refresh as fast as the eye can perceive. We use about 0.2 s for the parameter PC104MinTime. In view of the update limitations we observe, the sum of the values of $PC104MinTime^{-1}$ should not exceed about 50 s^{-1}.

Another important factor, which affects not the update frequency, but the validity of the displayed information, is the size of the UDP reception buffer allocated to the CVI synoptic program. If this buffer is too large a delay can build up between the reception of a message and its subsequent display. In our application we do not need to see all the values sent, but we do require the latest values, so the buffer must not be too large.

5 PRELIMINARY RESULTS AND FUTURE DEVELOPEMENTS

5.1 Reliability

GENEPI has proved to be stable in operation, the only delicate part is in fact the initial tuning. 39 elements interfaced to 11 of the final 15 PC104 have been in operation at the ISN for several months, and have proved to be as stable as GENEPI itself. In fact the accelerator recently was in operation for many days without a command sent to many of the PC104 controllers – which revealed a programming error so well known that it should have been avoided!

The only minor teething problem encountered was the occasional loss of the PPI configuration on some PC104 controllers. This seems to have been solved by reinforcing the protection of the RESET input of the controllers.

5.2 Developments

The control system was designed to allow the addition of as many identical man machine interfaces as needed, to take into account the geographical separation of the MASURCA reactor core and the physics data acquisition room. However the nuclear security authority has requested that if two control posts are present, only one can command at a given moment. The exact nature of the relation between the two control posts is under discussion.

When GENEPI is moved to the MASURCA reactor, it will be separated from the technical team which designed, built and commissioned it. It would be useful to be able to see the state of the machine from a distance. It is planned to achieve this using two modems and the Norton pcAnywhere software from Symantec.

REFERENCES

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