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Process Control for The Vivitron : the generator test set-up

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Abstract

The VIVITRON is a 35 MV Van de Graaff tandem electrostatic accelerator under construction at the CRN since 1985. About half of the parameters are controlled by equipments which are highly stressed by their physical environment : sparks, electrostatic field, X-rays, vacuum, and gas pressure. It needs a dedicated process control system. The described control system is used since early 1991 to perform the voltage tests of the generator. It provides important information for the accelerator tuning and for the full size control under development.

I. THE VIVITRON

The Vivitron Van de Graaff tandem accelerator, under construction at the Centre de Recherches Nucléaires at Strasbourg France [1] is designed to reach a terminal voltage of 35 MV at its terminal electrode [2]. The tank (51 m long and 8.4 m in diameter) is filled with SF_6 at 8 bars. The charging system is a belt running close to the tube at a speed of 10 m/s. The column consists of a glass fibre / epoxy insulating assembly, supported by insulated epoxy posts. Seven porticos, large field-shaping shields, and discrete electrodes improve the electrical field homogeneity [6].

The expected energy will vary from 20 MeV/A for the light ions to 5 MeV/A for the heavy ions. The intensity should go from 10^{12} pps for the light ions to 10^9 pps for heavy ones.

II. THE FULL SIZE PROCESS CONTROL

A. Specific problems

The process parameters are spread over a large area. The control equipment, located at high voltage inside the accelerator tank and in the injector, are highly stressed by their physical environment : 35 MV breakdown flashes, 440 kJ stored energy, 1.7 to 10 MV/m electrostatic field, X-rays, vacuum, and SF6 gas pressure [3].

B. Architecture

A multi-level structure is implemented between the process and the operator.

Level 3 is in charge of the field equipment I/O interfaces, the handling, switching, buffering and communication of the I/O data. Some of these field equipment crates are located inside the accelerating tank and in the injector. They are connected to level 2 by optical-fibre links crossing the 2 MV/m electrical field. At least one crate is requested for each electrical equipotential level. The small space available in some "dead sections" imposes the choice of a small-scale bus crate.

Level 2 is located outside the vessel at ground level. It achieves communication with level 3 and with level 1 and provides data switching, concentration and handling.

Level 1 includes the communication interface, the real time control and the operator interface.

III. THE SET-UP FOR THE GENERATOR TESTS

For the generator tests, only a reduced process control is needed. No beam control is necessary, no automation is required, the number of parameters is limited and no equipment crate is needed inside the machine. All the information is fed out at both ends of the tank. Optical wires are used for sensors and activators at high voltage. Shielded and protected galvanic wires are used for those at the ground level. Thus, data acquisition, data switching and operator interface are dominant.

A. Current flow and terminal voltage

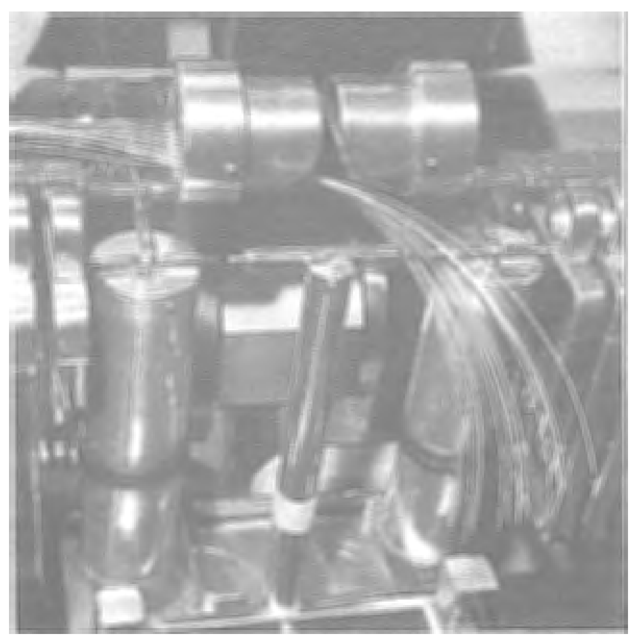

Figure 1. The current monitors in a dead section.

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The most important features for the generator tests are the control of the terminal voltage and the current flow inside the accelerator tank. The GVMs (Generating Volt Meter), which register the electric field along the tank in a standard electrostatic accelerator, are inefficient because the internal electrode structure shields the field in the Vivitron.

Therefore, no beam being available, the terminal voltage is given by the sum of all the inter-electrode voltages. The only way to determine them is to measure the current flow along the calibrated resistor chains in each section. We developed therefore a powerless floating current monitor for the Vivitron (Figure 1), starting from an original Munich design [4]. The information is fed to the outside ground level by a plastic optical fibre. The measurement range extends from 1 μA to 1 mA with an accuracy of about ±1%.

B. Set-up

This reduced control system has been designed on the full scale control scheme but with some limitations (Figure 2).

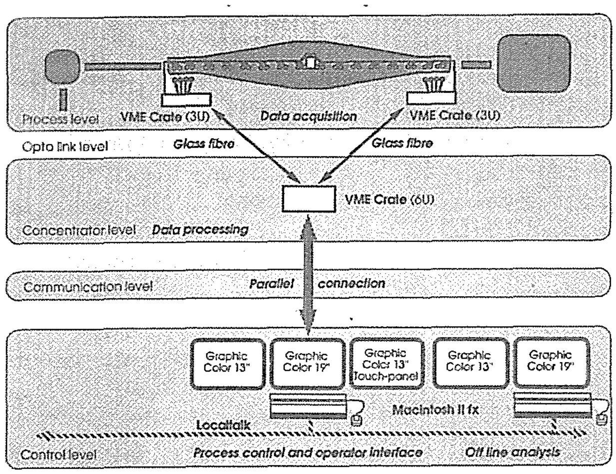

Figure 2. The control set-up for the generator tests.

Data acquisition and control is achieved by real time crates on levels 2 and 3, model of the final ones. Two diskless downloaded 3U VME crates on level 3, one at each end of the machine, are equipped with opto-isolated TTL I/O, 12 bits analog I/O, and timer/sequencer I/O boards. They communicate with level 2 by two serial glass fibre links. A 6U VME crate with hard disk on level 2 is in charge of the downloading of the former level 3 crates, of the message switching and of the data managing. The VME crates run under the OS9 real time operating system.

One standard, cheap, off-the-shelf available Macintosh IIfx 4/40 computer provides process control on level 1. It also provides the operator interface with multi-screen displays on one main 19' high resolution color screen (Figure 3), one 13' touch sensitive color screen (Figure 4) and one standard 13' color screen (Figure 5). A second identical computer near the first one is dedicated to the off-line data analysis (Figure 6) and the back-up. A third identical computer is devoted to the software development and to the process data base management. They are linked together by the Localtalk/Appletalk LAN. A Fastpath bridge provides access to a SUN server via Ethernet. They all run under MacOS. Communication between level 1 and level 2 is made by a NuBUS - VME Micron fast parallel interface. The two operating systems share a VME mailbox.

C. Tests of the generator

The tests of the generator started in the early 1991. A terminal voltage of 17.5 MV, the half of its nominal value, has been reached within a few weeks. Some tens of sparks occurred without disturbance of the process control.

About 100 parameters are controlled. Unidirectional and bidirectional currents are measured by about 60 current monitors and displayed as bar graphs on the central main permanent color screen (Figure 3). The column currents are displayed in real time as well as their differences in order to monitor the currents distribution and to locate current leaks. The belt charging currents and balance are also displayed graphically in real time. Intershield and terminal voltages are determined and displayed numerically on the same screen [7].

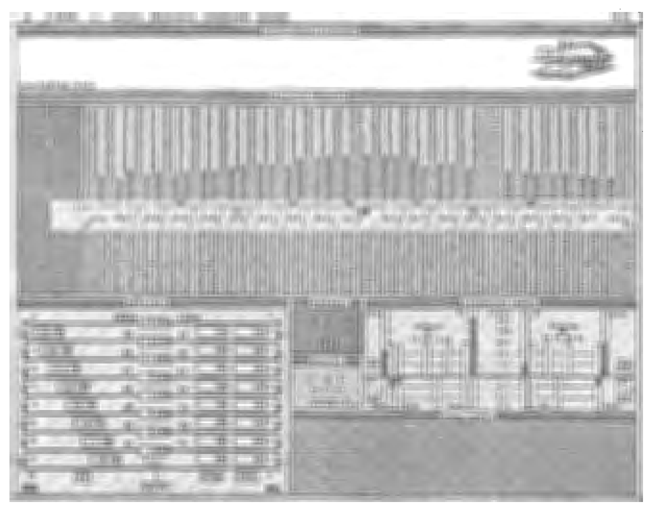

Figure 3. The operator main control display.

The control is achieved by the right hand touch sensitive color screen (Figure 4). Virtual push buttons switch the drive motors and the high voltage power supplies ON and OFF. They also control sliders which drive the charging systems. Interlocks are provided for security. The status is displayed by virtual green, yellow or red lights.

The left hand color screen is devoted to all the other functions : schematic display, wiring display, off-line and on-line

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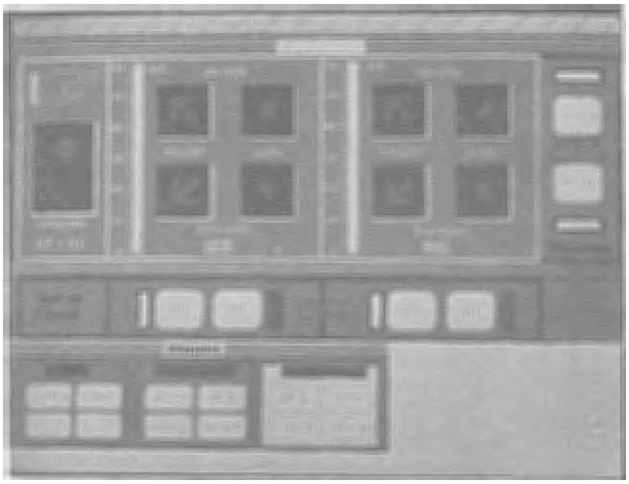

Figure 4. The command screen.

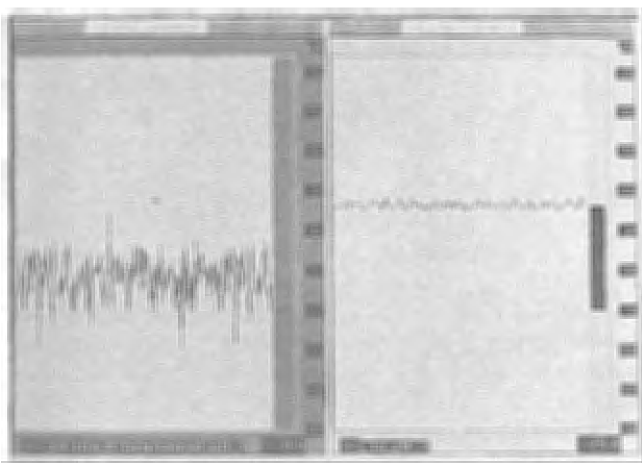

Figure 5. The real time current graph.

numerical data display, time chart of any selected parameters (Figure 5).

The refresh rate, of about 500 ms, depends on the computer load. All the data measured for 100 seconds are stored in a file with date and time on an operator command or automatically before and after a flash for later use and analysis (Figure 6). Every hour also, all the parameters are automatically stored on a backlog file.

The off-line analysis of the machine behavior and the study of the sparks can be achieved in two ways. The playback of on-line recorded data files by the control program performs continuous real time replay or step by step reading. The second way makes use of specific data analyzing programs or standard spreadsheet and graphic representation of data like EXCEL or WINGZ. A MACRO Language or Hyperscript are useful in this case. Figure 6 represents the currents flow inside the volume of the tank during a spark.

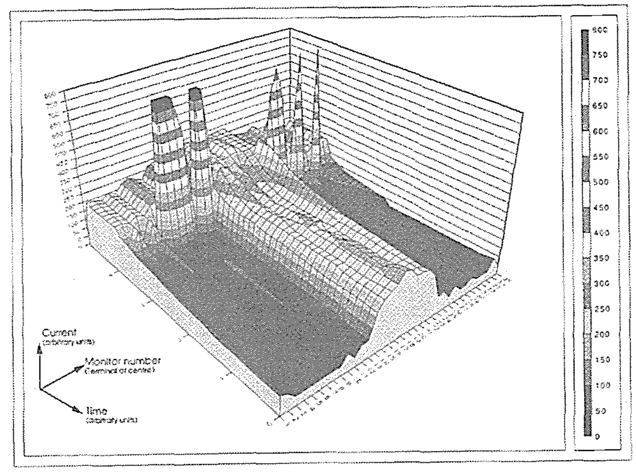

Figure 6. The 3D time / position current display.

IV. THE FUTURE

Equipment crates on level 3 will migrate inside the accelerator tank. The possibility to fit equipment crates inside the tank and their reliability have been tested in the MP accelerator. After more than one year and hundreds of flashes of up to 17 MV, we registered no transmission failure, no optical fibre failure, no measurement disturbance during flashes and only a few electronic failures [5]. The number of these crates will increase to more than ten.

The concentrator crates on level 2 will be connected to a high speed LAN and their number will grow. The process control and operator interface will be achieved by standard workstation clusters connected to the LAN. Processing power will grow from level 1 to levels 2 and 3. Software has to be more flexible.

V. CONCLUSION

The process control of the Vivitron had to be done in two steps. The first one has been used for the generator tests since early 1991. It represents a fast available control but it is reduced and limited in performance. Nevertheless, good experience is gained for the second step which concerns the full size control. Our aim is to perform a smooth transfer from the present status to the final one whereas the generator tests are going on.

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