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STATUS OF THE VIVITRON TANDEM OF STRASBOURG

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Although the first beams were produced in August 1993, many problems appeared over the following two years. It was only in 1996 that the accelerator became reliable, at least up to 18 MV, as the main obstacles were overcome. The past year was mainly devoted to the following improvements:
- A stronger joint for the belt.
- A significantly better stability of the terminal voltage and the beam intensity.
- Use of both up- and down-charge processes to load the terminal.
- Elimination of most of the local high-field regions.
- A new computer control system which is more efficient and extendeds to all of the machine's 1 500 parameters.
One major drawback remains i.e. the long time needed to dry the SF_6 gas after a tank opening.

1 Introduction

Except a short communication given in 1996 [1], the last time we attended SNEAP goes back to 1993. Meanwhile, the situation has been reviewed in papers presented at conferences in 1994 [2] and 1995 [3]. We recall that the first beam was accelerated in August 1993, but that the experiments with detectors began only in the middle of 1994. The following year was not a good one with the accelerator being shut down for 8 months due to belt problems. 1996 was significantly better, delivering a very respectable 3650 hours of "beam on target" despite eight openings, five being due to machine problems and two being scheduled openings.

2 Operations from 1 January to 30 September 1997

Apart from the shutdown in January which corresponded to an extension of the maintenance period at the end of 1996, the accelerator has only been stopped three times. The first time was for mechanical problems; a jammed Faraday cup at the terminal followed by a water leak in a cylinder of one of the SF_6 compressors which occured during gas transfer. The second was for the scheduled summer maintenance and installation of the down-charge system (see below). The third opening was again due to mechanical failure: play between the shaft of the belt-driving pulley and its key producing metallic filings which caused discharges and subsequent damage to the belt. It is important to stress that this breakdown was in no way due to problems with the charging system itself.

1 700 hours of "beam on target" were produced during the first nine months. As no other shutdown is forseen, we should reach 3 000 hours by the end of this year, less than was obtained in 1996. The main reason for this is that the summer opening was especially long; two and half months including the installation of the down-charge system. Time was also devoted to

[a] The "Institut de Recherches Subatomiques" (IReS) is the new name of the "Centre de Recherches Nucléaires" (CRN) since 1 April 1997, when it became a Unité Mixte de Recherche between the CNRS-IN2P3 and the Université Louis Pasteur.

measuring the beam transmission, to testing the pulsing system which is now operational, and improving the stability etc. Fig. 1 shows the distribution of time devoted to these different activities. Terminal voltage ranged from 10 to 17 MV. Drying periods represent a non-negligible part of the total time.

2.1 Machine Drying and Breakdowns

Since the summer, two additional drying towers have been installed taking the total flow rate to 450 m^3/h. Humidity is measured by two Panametrics meters, one at the exit of the dryers and another at the exit of the tank. Generally 5 days are needed to bring the rate below 5 ppmv at the exit of the tank. Unfortunately, this time is not sufficient to dry the insulators which are constructed of composite material, as are the posts and boards used as radial and longitudinal support. If one stops the drying, the moisture content increases rapidly. Generally 5 more days are needed before we begin to go up in voltage. Even then, discharges appear at voltages as low as 10 MV; around 5 per day initially. Some days later, their frequency drops to one or two per week at voltage as high as 17 MV. The humidity measured at the exit of the tank is then below 2 ppmv. With a few exceptions, these breakdowns are harmless for the accelerator.Although the propagation of the discharges are now well understood [3], their origin is not so obvious; residual dust, moisture in insulators and belt or column current instabilities being possible causes. Macroscopic electric fields are everywhere low; the highest static fields being 1.0 MV/m longidudinally and 7.2 MV/m radially at a terminal voltage of 18 MV. Because most of discharge traks are observed in the middle and near the bottom of the structure, not far away from the gas outlet, dust can be reasonably accused. During the summer opening, we took great care to clean thoroughly the inside of the tank and to avoid introducing any external dust.

2.2 Ion Sources

A few months ago, we bought by NEC a SNICS II Cs sputter source, particularly suitable for group II elements, like Mg and Ca. These proved difficult to produce with our homemade source, a copy of the well known type 860. Our original source is equipped with a spherical ioniser and the hole diameter in the extraction electrode was set to 3 mm in order to achieve a beam emittance below 5π.mm.mrad.$\sqrt{(\mathrm{MeV})}$. A separate source will be dedicated to ^{9}Be for both reaction and structure experiments.

2.3 Control and Command

All the 1 500 parameters of the Vivitron (sources, injector platform, voltage generator, vacuum devices, beam lines) are now computer controlled. Graphical displays and mathematical operations are possible. This system is the subject of a separate report [4].

2.4 Beam Facilities

The six installed beam lines and their associated detectors are shown in Fig. 2. One of the lines starts at a second 90 degrees magnet, the old analysing magnet of the MP tandem, which leads the beam to the new GAREL+ detector. The line D4 is used for two detectors, the neutron multidetector DEMON and the magnetic spectrometer Q3D. The later will shortly be replaced by the Manchester Velocity Filter.

3 The Charging System

3.1 The Belt

The charging belt is 100 m long and runs from one end of the tank to the other. After having suffered many disappointements with the so-called "Swedish" belt in 1995, we finally were able to go in touch with the italian manufacturer CIGO, who now deliver us satisfactory and reasonably priced belts, according to agreed specifications. These open-ended belts are then joined, initially by a local firm, but for the last 10 months, in our own institute. After running during 3 000 hours, the joint remained in an excellent condition. We have investigated in details the mechanical and electrical behaviour of the belts, in order to perfect the acceptance tests and assure a reasonable life time (longer than one year). This goal was achieved, the last belt recently being replaced after running for 14 months. Details will be given in an other report to this meeting [5].

3.2 Previous Configuration and Voltage Stability

Until June 1997 we used a conventional scheme. See Fig. 3. An up-charge shim stock connected to a current-regulated power supply is put at both ends in front of the driving pulley. Two collector shim stocks are installed up and down between an auxilliary roller and the power-generator pulley in the terminal electrode. Closed loop stabilisation is done by Corona needles facing the terminal and partly facing the discrete electrodes. Correction is frequency limited by the propagation time of the ions between the Corona needles and the terminal electrode (120 ms). But as we can observe on the column current and its fast Fourier Transform (FFT) (Fig. 4), mainly two cyclical defects of frequency 0.1 Hz and 1.4 Hz are present. The first is due to the belt junction, while the other one, which is smaller in amplitude, is probably due to manufacturing process and mechanical vibrations of the belt [6]. The well known relationship between the column current and the terminal voltage is:

$$U_{ter}(t) = Z(f).I_{col}(t) \tag{1}$$

In the Vivitron the impedance Z is a complicated function of frequency f. Simplified equivalent schemes of first- and second-order [7] are shown in Fig. 5. The small current ripple (1.4 Hz) gives a negligible voltage fluctuation of the terminal electrode. On the other hand, the big peak gives rise to a short (1 s) beam-intensity loss behind the analysing slits of order of 40 %. These slits are generally open to $\pm 1.25\,\mathrm{mm}$ in the dispersion (horizontal) plane. Assuming a displacement of the beam spot of a half of this aperture and knowing the dispersion of the beam line at that position, D = 10 m, we find a voltage instability of:

$$dU/U = 2.5 10^{-4} \tag{2}$$

or $dU = 3.8\,\mathrm{kV}$ at a terminal voltage of 15 MV.

The instability decreases when the terminal voltage goes up and increases when it goes down.

As our power supplies are computer controlled, a first idea was to correct the main effect by applying a cyclical signal, synchronized with the belt rotation, 2.5 s in advance to the emergence of the defect, i.e. the time needed for the charges to reach the terminal collector shim stocks. Unfortunately, this did not work. A square impulse of a width of 0.1 s spreads out during its travel to a roughly gaussian signal, 0.7 s large at the base.

Up to now, stripper modulation has not been applied because of pratical difficulties.

3.3 The Present Configuration

Since the beginning of the project, a double charge system with both up- and down-charge had been considered in order to achieve what the designers of the project called "decoupled structure" [8,9]. The initial idea was to load the four sections of the belt with charges of opposite sign on opposite parts. This arrangement is shown in Fig. 6. This system was installed in August. This took 1 month to install since we had to change the two double-shielded boxes containing all the electronics inside the terminal electrode. The other advantage should be the possibility of correcting the belt-joint effect by controlling the down-charge current, as we envisaged doing with the up-charge power supplies earlier. This will be undertaken in the near future.

Uncontrolled positive charges collected by the shim stocks reach the terminal, so that the down-charge power supplies cannot regulate low loading current ($< 20\,\mu A$), even at the OFF position. The consequence is that we have to sustain a terminal offset voltage of roughly 4 to 8 MV, but as can be seen, the column current (Fig. 7) and the beam intensity are both more stable as in the previous configuration.

4 Conclusion

Four years after having accelerated the first beam, one can say that the Vivitron is now running reliably up to 18 MV. Some mechanical parts installed 10 years ago display weaknesses and have been the cause of several shutdowns. The next step will consist of increasing the current drawn down the column by lowering by a factor of two the resistance of the potential divider in order to reduce the perturbated part relative to the DC level.

Unfortunately, we have to cope with a major drawback; the long time needed to dry the gas (2 weeks instead of 2 days for more conventional accelerators). Despite this we have still been able to carry out an important program of nuclear research while at the same time improving the machine performance.

Much work remains to be done; mainly to localise the origin of the discharges and to try to reduce the overvoltage between discrete electrodes in case of the voltage transients. Then we should be able to reach 25 MV. This is of course still far from the original design value of 35 MV but will nevertheless provide an European accelerator capable of first-class nuclear physics research.

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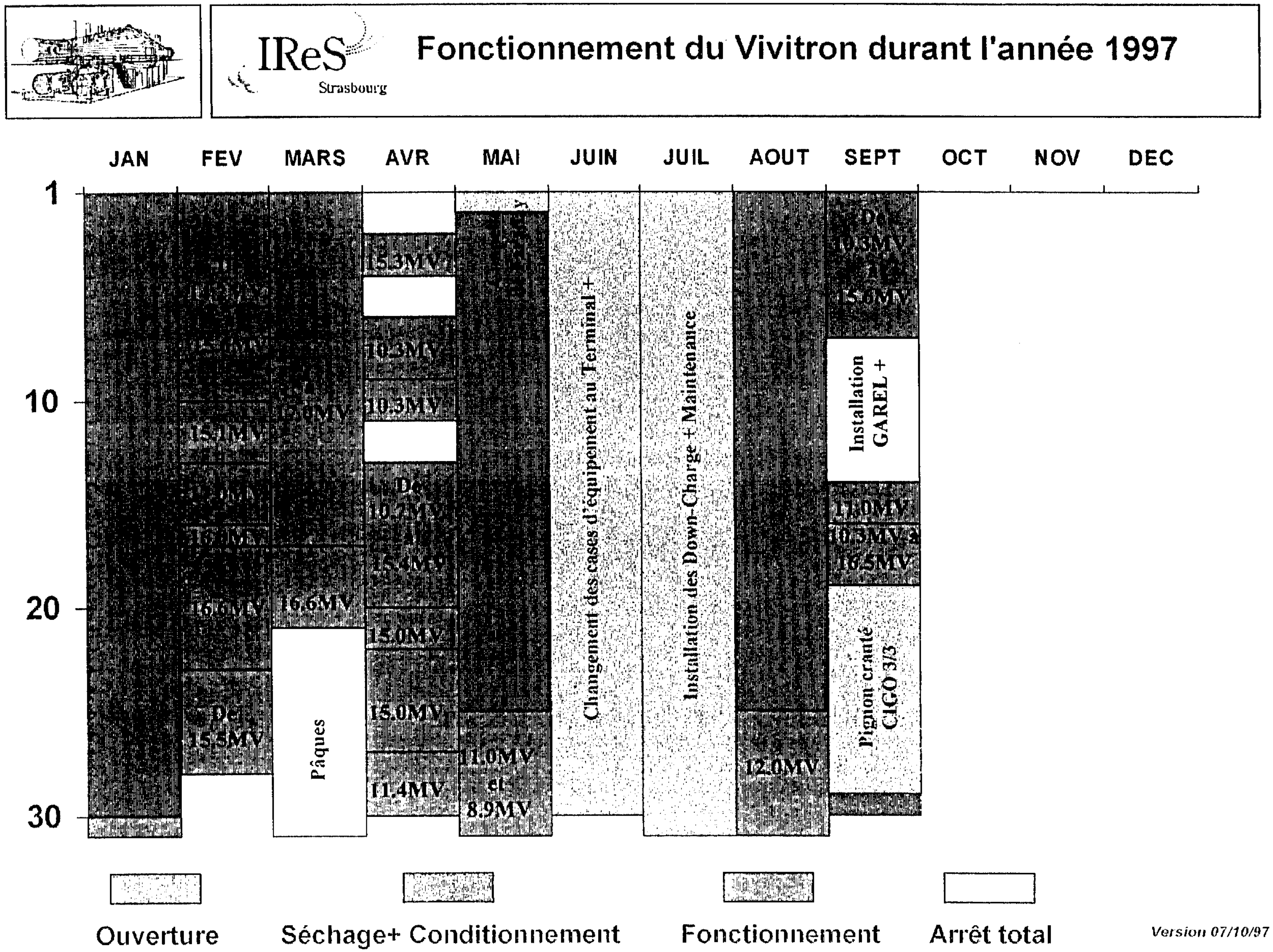

Fig. 1 : Vivitron Operation during 1997 :opening, drying and running time

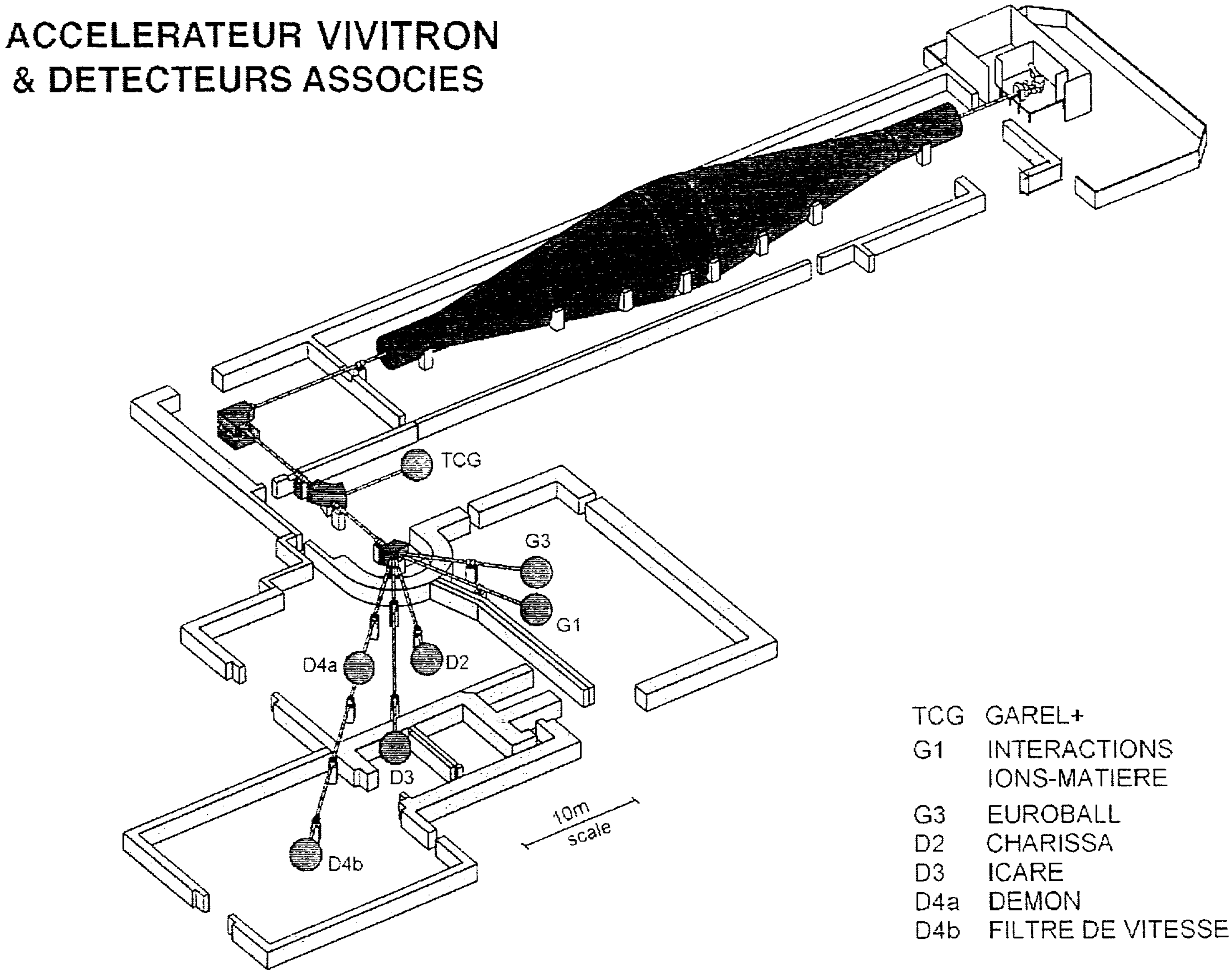

Fig.2: Vivitron accelerator and associated detectors

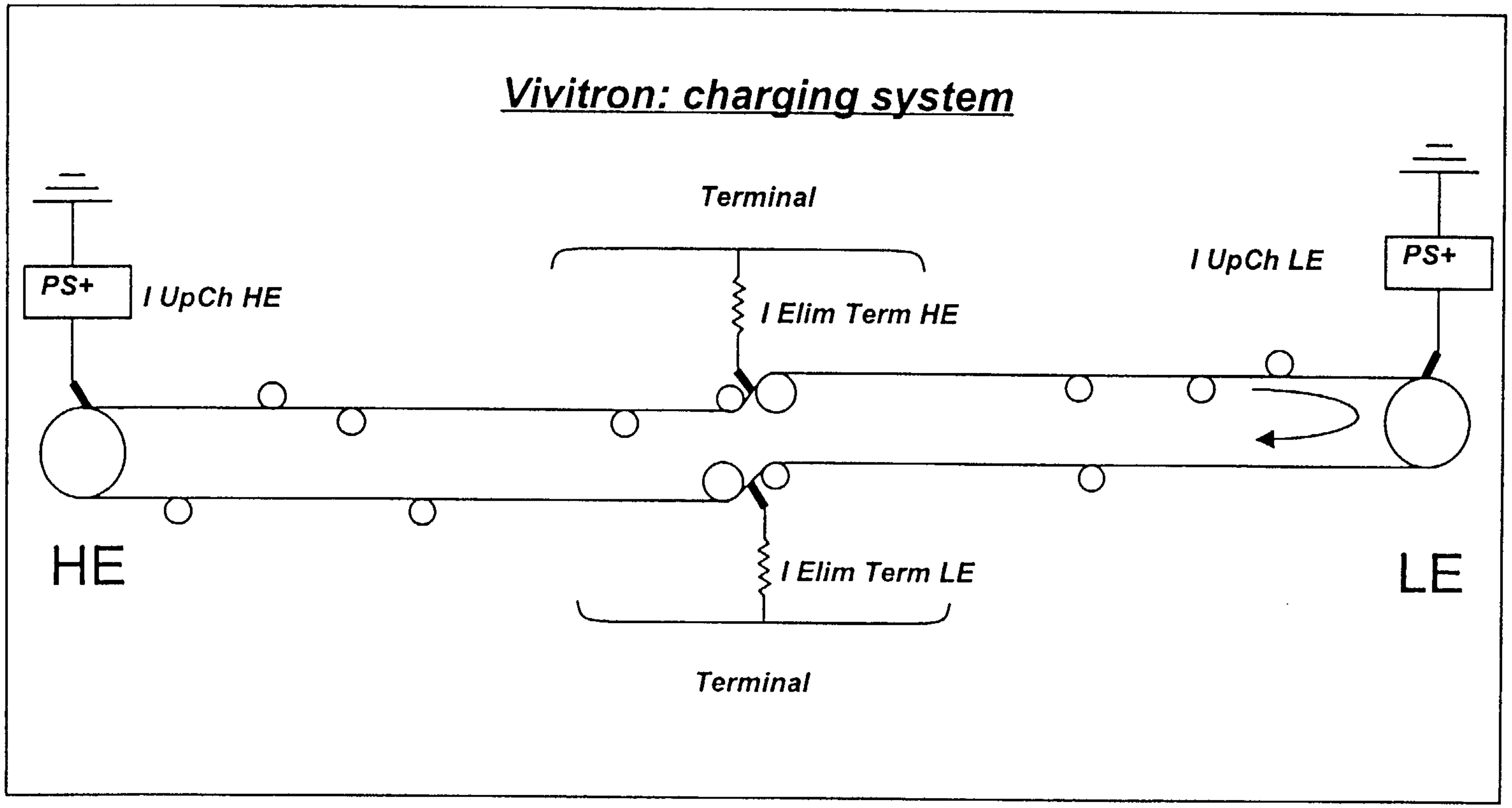

Fig. 3: Conventional charging system with positive up-charge power supplies at both ends and two collector shim stocks at the terminal

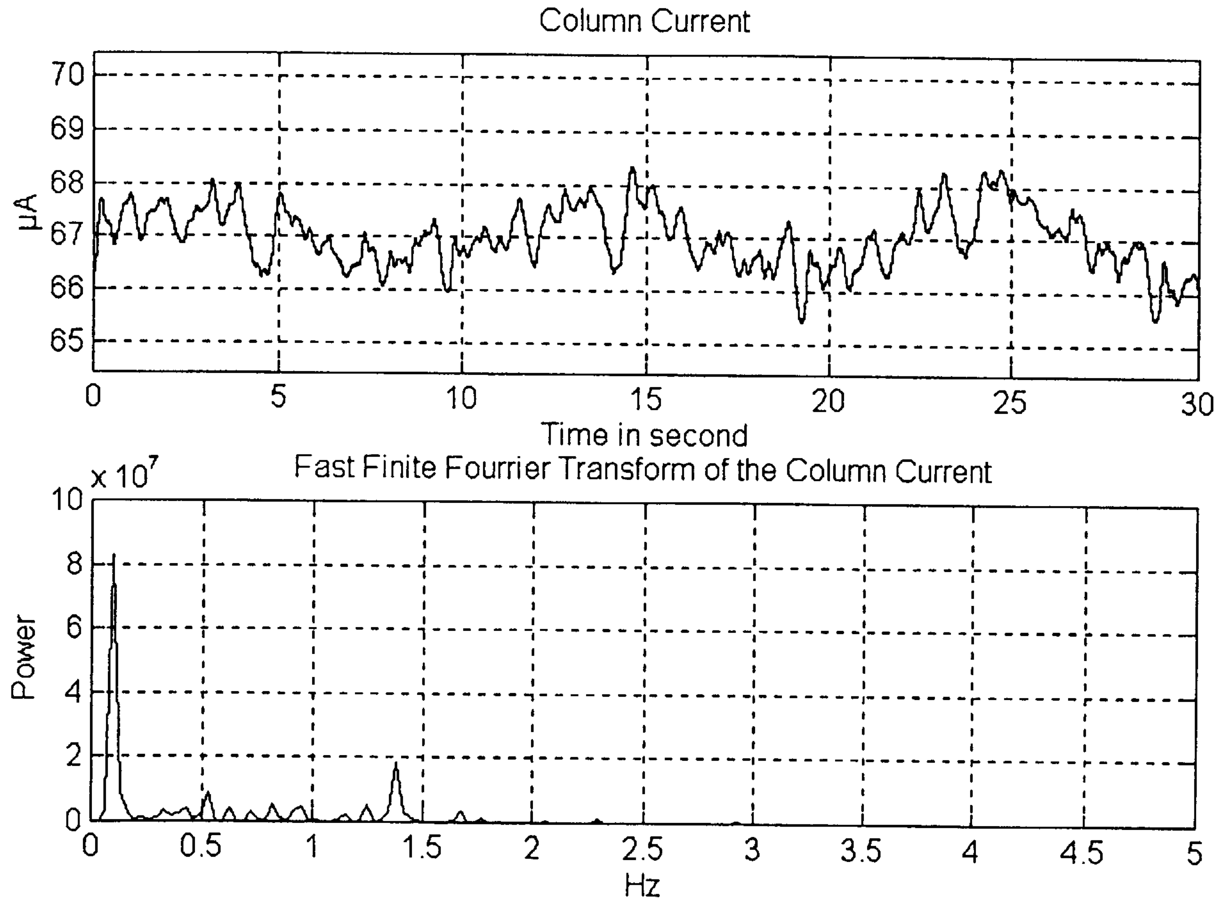

Fig. 4 : Column Current and its FFT in the previous charging system, for an operating voltage of 15.4MV

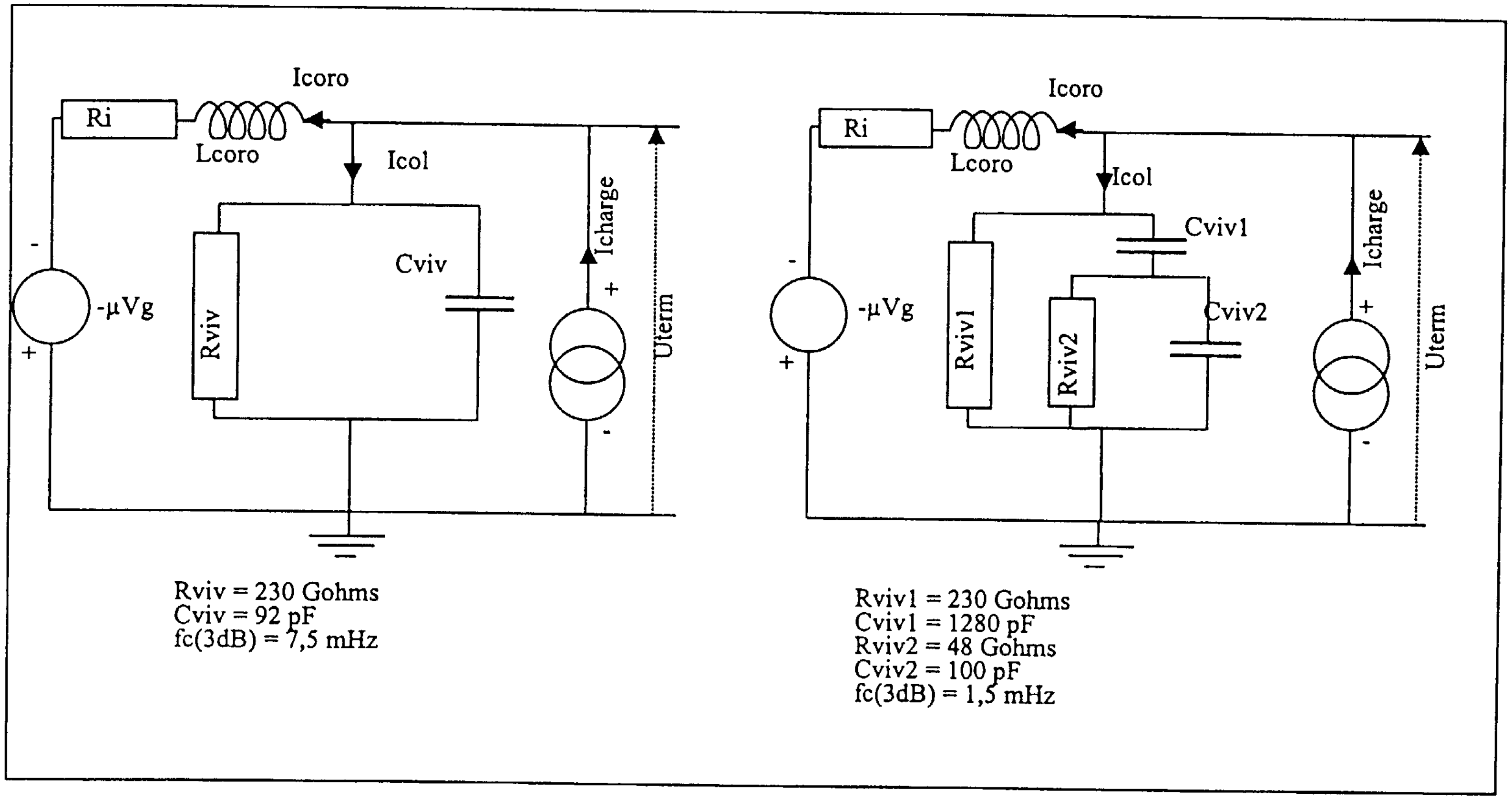

Fig. 5: Equivalent scheme of first (left) and second order (right) of the Vivitron charging system

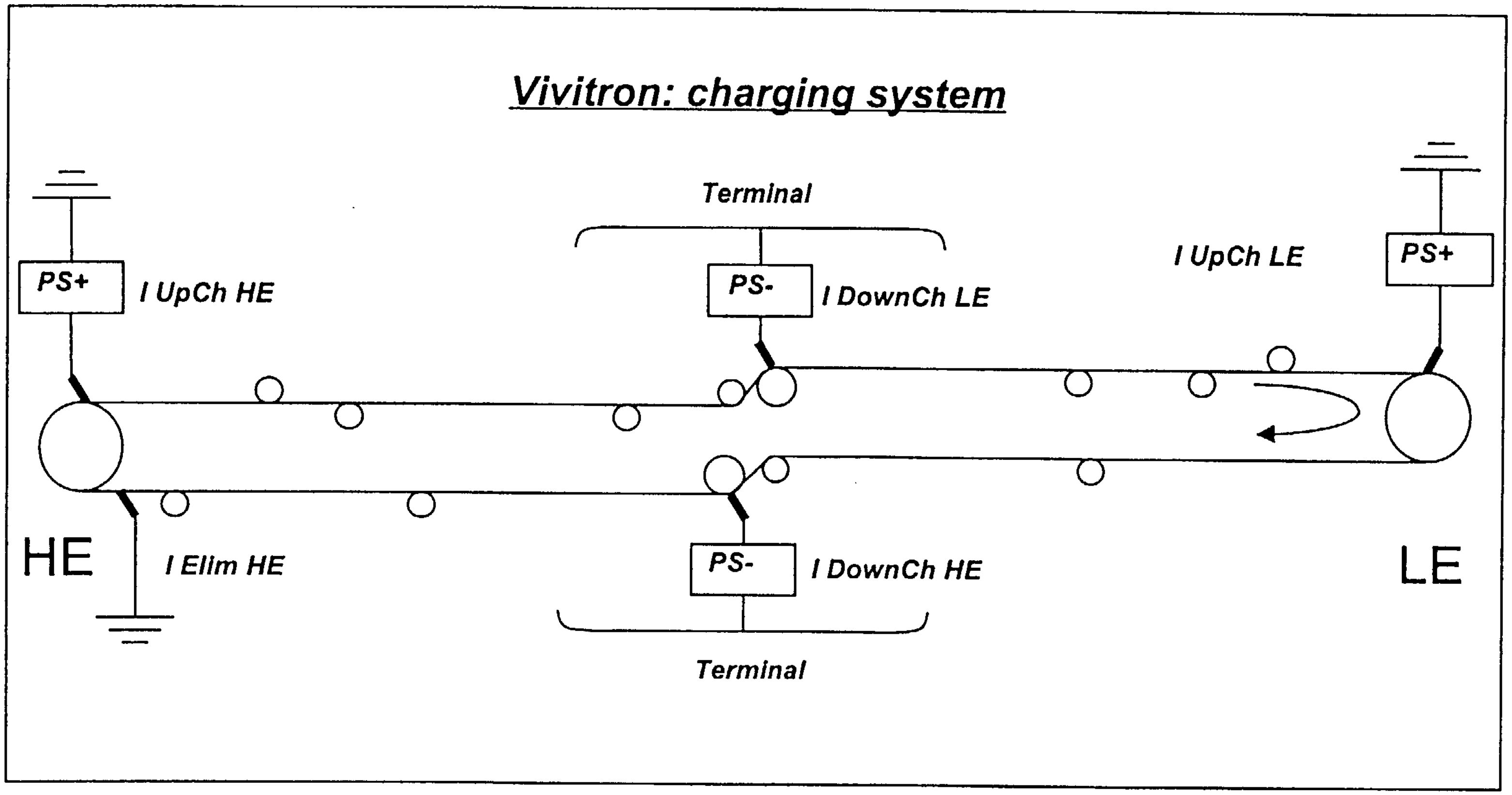

Fig. 6:Current charging system with positive up-charge power supplies at both ends and negative down-charge power supplies at the terminal

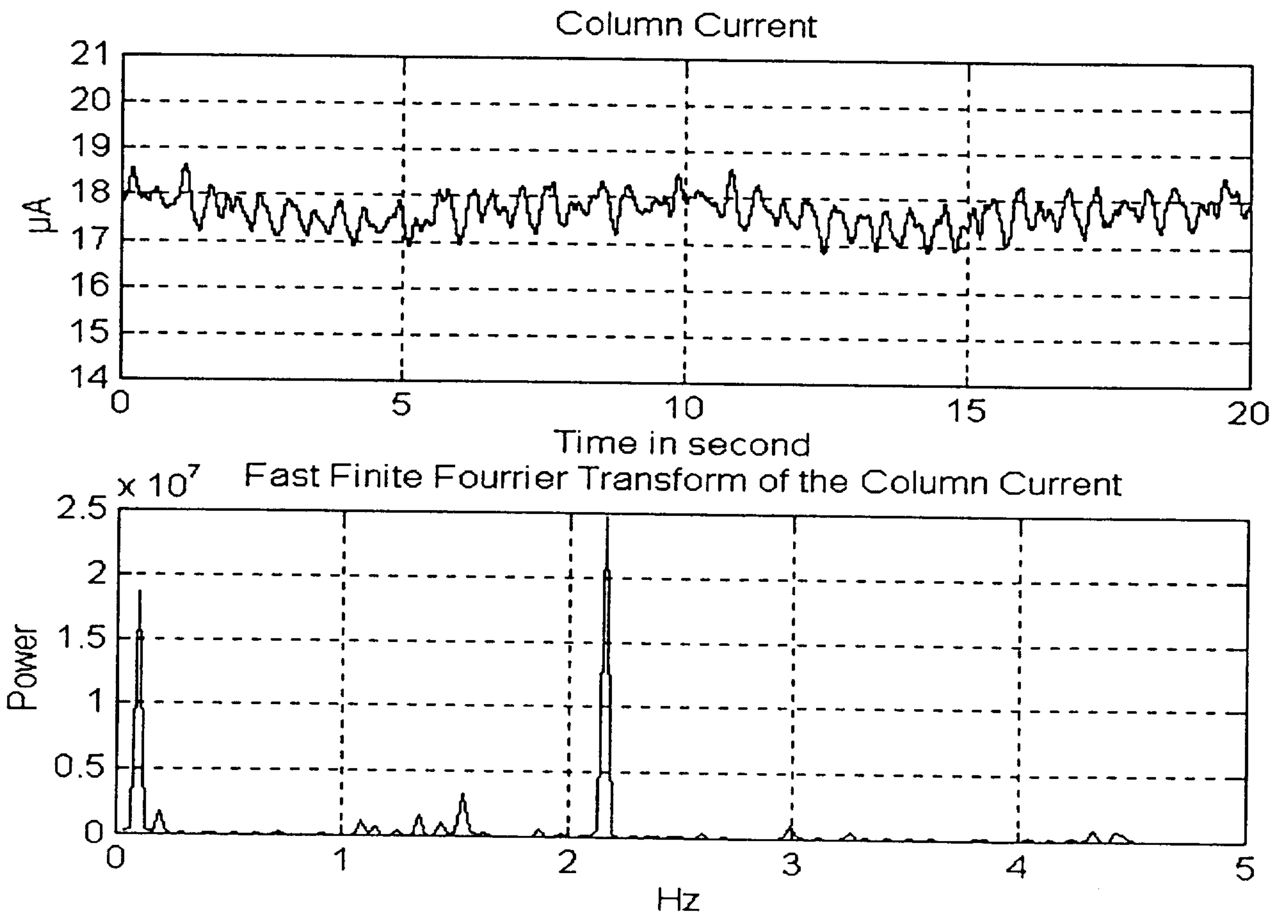

Fig. 7 : Column Current and its fast FFT in the current charging system