THE VIVITRON: EVOLUTION OF A WORKING ACCELERATOR

T.Foehrenbacher, J.Heugel, E.Jegham, N.Lahera, L.Michel
F.Osswald, R.Rebmeister and the VIVITRON Group
Institut de Recherches Subatomiques
UMR 7500, CNRS-IN2P3 et Université Louis Pasteur
23, rue du Lœss, 67037 Strasbourg-Cedex2, France

Abstract

Although the first beams were accelerated in August 1993, the major scientific exploitation of the machine really got underway in 1996. During each of the two years since then, more than 3000 hours of beam on target were delivered to the scientific community, at terminal voltages between 8 and 19 MV. In parallel with the scientific programme, three important technical goals have been pursued. Firstly the installation of a completely digital control system has been carried out. This enables the storage of all of the accelerator's 1500 parameters, offers simpler operation and, in particular, allows a better understanding of the machine's behaviour. Secondly, the improvement of reliability through a more efficient gas-drying system has been completed. The third goal of better stability and good high-voltage performance has been partially achieved through the use of a more satisfactory charging system for the belt (installation of two down-charge power supplies inside the terminal) and the elimination of some electrically high-stressed regions.

1 INTRODUCTION

The two last years' efforts were directed mainly at the following goal: greater reliability of the accelerator functioning and an improvement of the stability of the energy and beam intensity at a voltage level reaching progressively 20 MV.

Inside maintenance and operation amounted to eight tank openings during 1996, four during 1997 and none during the first semester of the present year. During the first five months of 1998, 3200 hours of beam have already been delivered against 3300 for the last full year. This demonstrates that our goal is being achieved.

2 RELIABILITY CONCERNING PRACTICAL PROBLEMS

One of the Vivitron's particularities is the glued joint in the unusually long charging belt (100 m) [1]. This joint gave rise, during a long time, to a lot of mechanical and electrical troubles. The mechanical aspect is now solved [2]. The current belt has now (1998, June 1st) totalled more than 5000 hours, agreeing with the 6000 hours estimated life time, corresponding to over a year running time without maintenance. The driving rollers are fastened to adjustable housings allowing two remakings of a new joint. An efficient drying procedure and the respect of tank cleanness completes the panoply of changes to achieve good reliability.

3 BEAM STABILITY

Stability is an important factor of machine characteristics. Instabilities are suspected to reduce the maximum terminal voltage which was 19 MV before the improvements related below [3].

Since using "down-charge" power supplies, the terminal electrode charging is more uniform and the voltage is no longer affected by the belt charge discontinuity, due to the joint crossing the terminal electrode as was the case before with only "up-charge" power supply at both ends of the tank [4]. The first setting of the power supplies defined in the project [5] led to a symmetric charge on the four sections of the belt shown in figure 1.

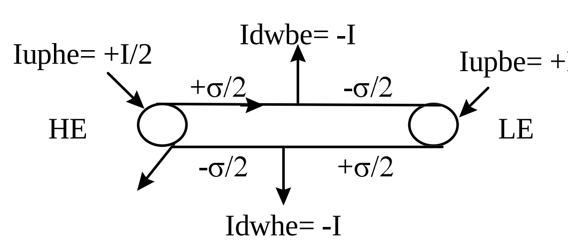

Figure 1: Layout of the Vivitron charging system. Currents and charge densities on the four sections of the belt are the design values.

Despite the column currents flowing more uniformly in the resistive divider [4], the stability of the beam current I_{ana}, measured downstream of the analysing slits, was still affected by a cyclic perturbation of 0.3 s every 9.76 s (once per belt rotation).

4 INFLUENCE OF THE DISTRIBUTION OF CHARGES ON STABILITY

A systematic investigation of beam stability versus the current intensities delivered by the four power supplies of the charging system has been undertaken. The checked currents were:

- the beam current I_{foc} measured in the Faraday cup FC_{foc} at the entrance of the terminal electrode, a cup whose opening has the same diameter as the stripper canal, and
- the beam current I_{ana} already mentioned.

Each 30 s long record, done at the 3 machine voltages 10, 12.5 and 15 MV was followed by the calculation of the average and the standard deviation of these currents. This is one of the possibilities offered by the present control system of the VIVITRON [6]. The column current I_{col} flowing through one of the four chains of the voltage divider was also recorded.

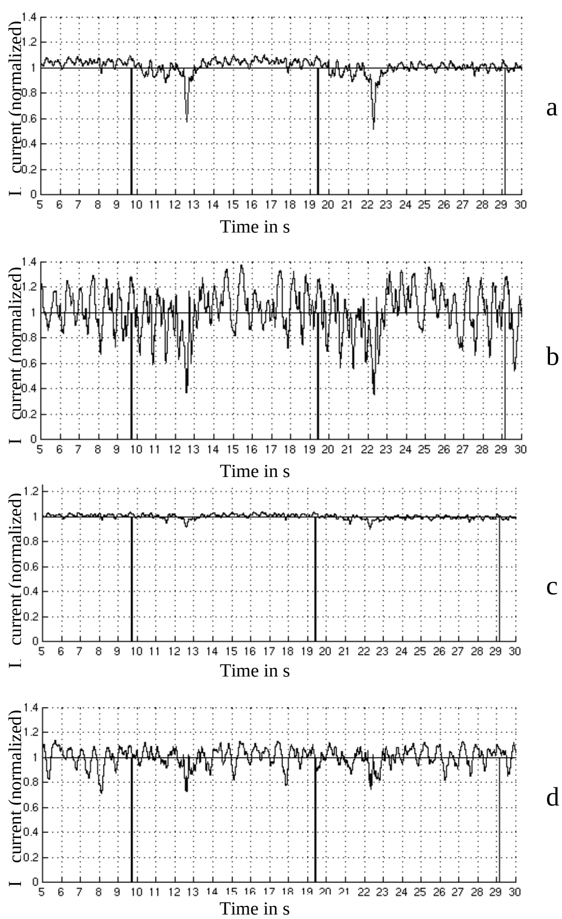

Figure 2: Record of the beam currents I_{foc} at the entrance of the terminal electrode and I_{ana} downstream the analysing slits for:

a,b: the initial setting of the current supplies,

c,d: the best setting at present.

Vertical straight lines represent the belt synchronisation signal.

A first improvement could be achieved by varying only the "up-charge" current supplies keeping the "down-charge" current supplies fixed. Influences on I_{foc} and I_{ana} were minor and they still were affected by the cyclical perturbation mentioned in the previous paragraph.

In a second step, the setting was improved by also varying the ratio between the high-energy and low-energy "down-charge" currents I_{dwhe}/I_{dwbe} while keeping their sum $(I_{dwhe} + I_{dwbe})$ and thus the voltage of the terminal electrode constant. As shown on figure 2, we note that the perturbation due to the joint has totally disappeared and that the instabilities whose previous standard deviations were:

$$\sigma(I_{foc}) = 5.7\%$$
$$\sigma(I_{ana}) = 23.1\%$$

are improved to:

$$\sigma(I_{foc}) = 3.1\%$$
$$\sigma(I_{ana}) = 8.3\%$$

This result was reached with the setting shown on figure 3.

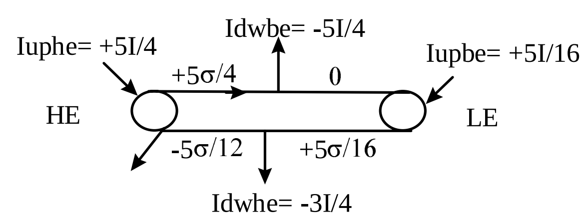

Figure 3: Layout of the VIVITRON charging system. Currents and charge densities on the four sections of the belt correspond to the present setting.

5 INTERPRETATION OF THE PHENOMENON

5.1 The I_{foc} current

Because there is no energy filtering upstream of the FC_{foc} Faraday cup, the intensity fluctuation observed with the previous settings is obviously due to a beam beat. A horizontal beat is difficult to explain but, on the other hand, a vertical beat could be the consequence of a local variation of the voltage gradient which periodically affects the accelerating electrodes (alternately ±14° vertically inclined).

The Vivitron control system not only records the currents but also provides a synchronisation signal (a photo-electric cell reads a black strip painted 13 cm upstream of the belt joint) as shown on figure 2.

Knowing the belt's characteristics (length L=101.3 m, revolution period T=9.76 s) one observes that voltage gradient perturbation occurs when the belt joint is about 4 m away from the low-energy (LE) side driving roller on the bottom section, near electrode n°58 of the SA2 accelerator tube. At that place, the belt is very close (80mm) to the gradient rods which are installed on the top of the accelerator tubes and the beam energy is still low. A capacitive influence, which has still to be detailed and quantified, could explain such a behaviour.

5.2 The I_{ana} current and the voltage stability of the accelerator

As long as the I_{foc} current is perturbed, the I_{ana} current is also affected (Figure 2a,b). With the final setting, one observes that I_{foc} is perfectly stable and that the perturbation which occurs once per revolution has also disappeared on the I_{ana} current (Figure 2c,d). Then the residual instability of I_{ana} only reflects the voltage fluctuation of the terminal electrode.

During these measurements, the horizontal and vertical apertures of the analysing slits were set to:

$$x= \pm 1.3\text{mm}$$
$$y= \pm 2.5\text{mm}$$

The beam transmission through these slits was found to be 0,970. If the intensity distribution of the beam is supposed to be 2D Gaussian, then the standard deviation of this distribution in the both planes are:

$$\sigma_x = 0.56 \text{ mm}$$
$$\sigma_y = 0.97 \text{ mm}$$

The momentum dispersion of the analysing dipole is 10.6 m at the slits position, so the peak-to-peak fluctuations of the terminal voltage or the beam energy stability are:

$$dU/U= 2.0 \ 10^{-4}$$

The frequency of this residual instability is 0.72 Hz and is perfectly tolerable.

One of the aims has been achieved by taking away the cyclical perturbation due to the belt joint which affected both the terminal voltage and the analysed beam intensity.

6 ELECTRICAL CHARGES ON THE BELT AND FIELDS INSIDE THE BELT

As an example, we have estimated the charge density deposited on the four sections of the belt and the resulting electric field between them for the highest voltage used in our measurements, i.e. 15 MV.

The relationship between charge density σ and current I injected by the power supplies via shim stocks is:

$$\sigma= I/w.v$$

where: w = 0.38 m represents the width of the belt and
v = 10.4 m/s represents its speed.

At 15 MV, the down-charge current needed with a corona current of 22 µA is:

$$I = 45 \ \mu\text{A}$$

so one finds:

$$\sigma= 11 \ \mu\text{C/m}^2$$

The average longitudinal electric field in the machine is:

$$E_l = 0.75 \text{ MV/m}$$

For the initial symmetric setting, the charge density was 5.5 µC/m² and the electric field between the sections of belt 0.62 MV/m, which is of the same order of magnitude as the longitudinal field E_l. In the present situation, the charge densities are definitively lower on the low-energy (LE) side, respectively 0 and +3.4 µC/m² for the upper and the lower sections. The corresponding field is 0.19 MV/m. Conversely, on the high-energy (HE) side, the charge densities are higher on the upper section, +13.8 µC/m², and little changed on the lower section, -4.6 µC/m². The corresponding field is of course also higher, 1.04 MV/m. These results suppose a decoupling between the column field and the field inside the belt. This is not perfectly achieved. A balance between the deposited and the collected remaining charges by shim stocks installed in front of the HE belt driving roller (Figure 3), shows that the parasitic charges (tribo-electricity and others) are low and do not much change the values reported above.

7 CONCLUSION

One of the causes of instability, specific to this machine and problematic for the users has been eliminated. But to know how much the voltage limit has been enhanced, is difficult to estimate. Beam quality is improved, and because of less perturbations on the column current we can think voltage limit is also enhanced (voltage limit measurements are scheduled two weeks after the present conference). The other improvements, especially those concerning the belt, whose lifetime is now approximately 6 000 hours, make it possible to reduce the number of tank openings to two, one needed for the two-month summer maintenance during which important changes can be made, and another much shorter one, about two weeks, to remedy possible problems which may occur.

REFERENCES

[1] M. Letournel and the Vivitron Group, "The Strasbourg project. A 35 MV Vivitron Tandem", Proceed. EPAC Conf., Rome 1988, pp 7-11.
[2] F. Osswald & al, "Development of the belt charging of the Vivitron", Proceed. SNEAP Conf., Ed. World Scientif. Publ., Juelich 1997.
[3] Y. Thiery, J. Gao, J. Le Duff, "3D investigations of the 35 MV tandem Vivitron", Nucl. Instrum & Methods A 378, 21-26, 1996.
[4] R. Rebmeister, E. Jegham, N. Lahera and the Vivitron Group, "Status of the Vivitron Tandem of Strasbourg", Proceed. SNEAP Conf., Ed. World Scientif. Publ., Juelich 1997.
[5] J.M Helleboid, "A charging system for the Vivitron", Nucl. Instrum & Methods A 287, 99, 1989.
[6] L. Michel & al, "The control and the command of the Vivitron", IEEE Transactions, Real Time Conf., Vol.45, N°4, 1998.