FIRST RESULTS WITH THE CHARGING SYSTEM OF THE VIVITRON

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Abstract : An original, Van de Graaff type, belt charging system has been designed, built and assembled for the Vivitron, a 35 MV Tandem accelerator. Together with a detailed description of it, experimental studies, tests in a pilot machine and the results of the very first tests of the real system are reviewed.

Introduction

The Vivitron, a 35 MV electrostatic Tandem accelerator, is under construction at the C.R.N. [1]. Part of it, the high voltage generator is presently near completion.

It is fed by a Van de Graaff type belt charging system whose design, although classical in its principle, includes number of original features in order to fit various specific constraints imposed by the general design of this accelerator [2]. Assembly of the whole charging system has been completed and very first tests done at the end of 1989. In addition to that, experimental studies have been partly continuing on a one-to-one, half length, test bench while intensive mechanical and electrical tests have been made in a 7 MV single stage pilot machine.

Special Features of the Design

General layout of the charging system shown in Fig. 1 could be seen wether as a usual industrial conveyor or as a conventional belt charging system. However there is number of fundamental differences which makes of it a very specific arrangement.

In all the conventional systems the charged belt is always strongly electrically coupled with an arrangement of gradient rods in order to limit the local potential developed from the charge density onto the belt.

On the contrary, the present design (Figs. 1 & 2) is based upon the principle of the decoupled structure [3, 4] (Fig. 3), where the field from the charge density onto the belt is almost confined between the two symmetric up and down charged portions and is there uniform, while the coupling with the rest of the accelerator, outside the two belt portions, is low, taking advantage of the much better voltage retention for a uniform field [4]. In addition, because the external field is low, external gradient rods can even be suppressed, which still enhances the decoupling effect, while reducing the number of conducting pieces in the column.

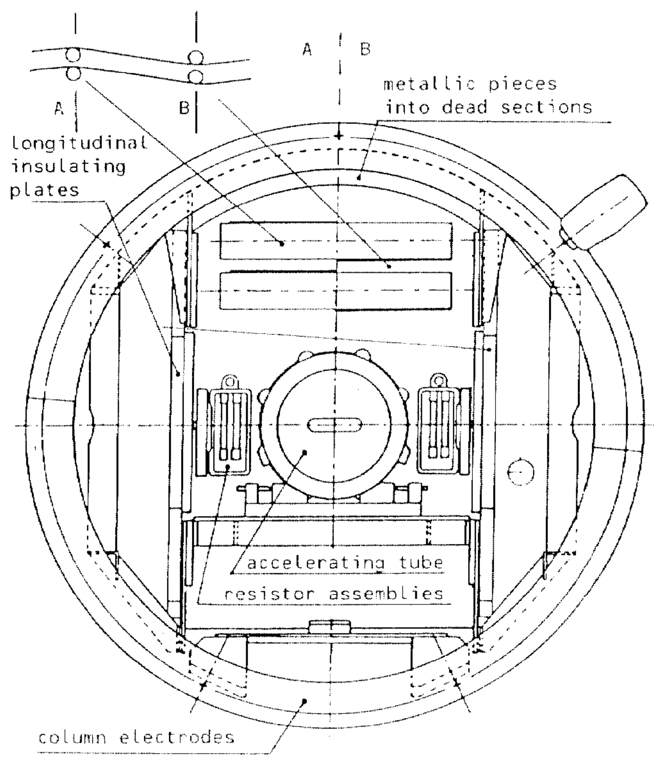


Fig. 2 Column cross-section and belt location in two successive dead sections : A (left), B (right)

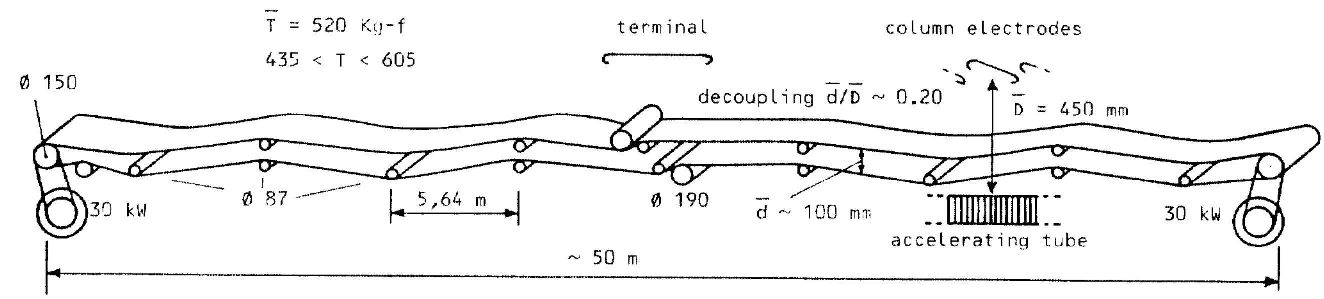
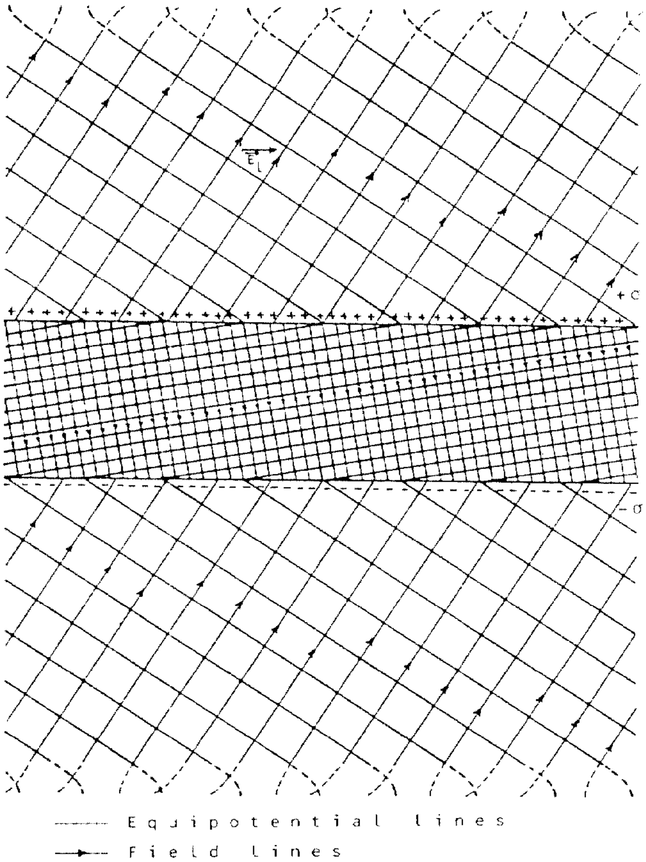


Fig. 1 Sketch of the final mechanical belt arrangement for the Vivitron.



ig. 3 Potential and field lines for a typical decoupled structure with ecual up and down charge densities

As the column is not compressed but only supported it could not bear the longitudinal stress from the belt tension. thus, it has been decided to use a ~100 m long belt through the full length of the machine, so extending to the charging system the symmetry of the accelerating tube and column. That also gave us the opportunity to run a double up and down charge arrangement (Fig. 4). For the required total current the charge density onto the belt and the resulting field are then only half of the value for a conventional system. The commutation arrangement also shows on Fig. 4 is such as to respect the symmetry of the decoupled structure + or - σ) using a minimum of ionisers, only one of which being a "collection" one, the other four being charging, current regulated, ones.

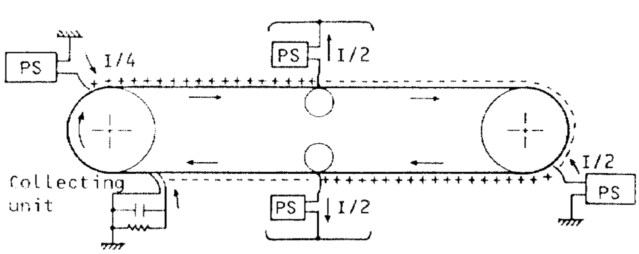


Fig. 4 Symmetrical belt arrangement with four oppositely charged portions, each, running from the ground to the terminal, then back to ground. The commutation system is illustrated for a total current I.

As a consequence of the previous features the belt speed can be significantly lowered for a given total current so reducing the power loss from the gas friction (∝ v 3) and according the parasitic charge generation. However the 10 m/s speed is still a lot higher than 1.5 m/s max for such long industrial conveyors with which other main difference apart electrostatic aspect, is forces from transported charges resulting in totally different arrangement and number of supporting rollers.

Test Bench Experimental Studies

As we lacked information both about the Swedish belt characteristics and also about the running conditions of a 100 m long belt (5 x that of the MP, 10 x the longest Swedish belt ever used in an accelerator) at 10 m/s high speed (10 x usual speed for long belt conveyors in industry) and high power (> 30 KW), a one-to-one test bench but only ~ half length (27 m) with no SF6, no pressure, no voltage and limited power (~ 8 KW) was built, both to confirm the theoretical design and to investigate various parameters such as :

- Elastic and permanent lengthening to the belt under tension,
- Required mechanical stress,
- Sliding coefficients,
- Sags and related forces versus supporting arrangement,
- Torques and related power,
- Static and dynamic tracking (mean trajectory and its stability),
- Double drive of the belt,
- Electrical power generation from the belt.

The results have confirmed most of the previous theoretical design [4] but also led us to make necessary modifications and possible improvements.

Main Characteristics

As the Strasbourg MP is capable of running with a charge density of 3 nC/cm², the Vivitron belt speed has been fixed at 10 m/s (24.5 m/s for the MP) for which σ = 2.6 nC/cm² for I = 500 μA. Commutations will be ensured in a first stage by stainless steel screens (Ø ~ 5 mil, 80 mesh) or sheets (50 μm thick).

The 520 mm wide, 100 m full length Swedish belt is driven at 10 m/s by two 150 mm diameter crowned end pulleys, each powered by a 30 kW asynchronous motor, sharing the load as to avoid extreme values of mechanical stress that the belt could not withstand. There is only one 127 mm diameter guide roller with an angle of 6° at one end station. Supporting is ensured by a total of fourteen rollers, uncluding twelve Ø 89 mm (2200 rpm) distributed in every other dead section, that is to say, every 5.64 m (Fig. 1) and two others Ø 112 mm associated with two 4 KW, Ø 190 mm alternators in the terminal electrode. The arrangement has been chosen taking into account the characteristics of the belt, so as to ensure the highest possible decoupling factor (~ 80 %), while keeping the running correct whatever the load, with a minimum number of supports. The average stress is 2 x 520 Kg-f which corresponds to ~ 1.4 % lengthening (about 3 times more than for HVEC belts) with which at least 40 KW could be transmitted. The need is ~ 33 KW, including the electrical work P_e = 35 MV x 500 μA = 17.5 KW, the gas friction P_f ~ 3.5 KW (P_f > 14 KW) for the MP), and the provisional power in the terminal P_u = 8 KW

Test in a 7 MV Pilot Machine

A model charging system about similar to the initial design previously described [1], including one Ø 315 mm driving pulley and one pair of Ø112 mm guiding rollers with an angle of about 30° at each end, has been assembled and tested. However, guide rollers had only 100 mm diameter with an angle of 36°, rest mechanical tension was only 380 Kg-f for 520 Kg-f, power was less than 8 KW for 33 KW while speed was 15.6 m/s for 10 m/s for the Vivitron.

Both mechanical and electrical behaviour have been explored :

Equivalent scaled nominal voltage of 6.5 MV for 35 MV and current of about 200 μA per run for 125 μA have been demonstrated.

However,serious difficulties have also been put in light :

First one, which have been foreseen, is the high triboelectric parasitic charge generation which does not exist without guide rollers. Initial currents of more than 200 µA have been observed that have once destroyed a new belt developping at once strong surface sparking resulting in carbonised electrical trees. The currents decrease quite fast down to non dangerous value and continue to go down in hours or one or two days to a residual level of some µA up to 20 µA or so, that is still undesirably high for a correct running of the Vivitron.

The second difficulty brought to the fore is the severe limitation of the belt lifetime compared with several thousands of hours reported and experienced by ourselves with such a belt in same conditions, but without guide rollers. It is due to the early tear of the glued splice.

None of these problems has been encountered up to now, as they are probably both caused mainly by the winding (counter flexion) of the nitril face of the spliced belt over small diameter rollers with a large angle which situation had never been experimented.

Solutions to these difficulties were then investigated :

In the past we had already looked at the possibility to have an endless 100 m long conventional HVEC accelerator belt manufactured but we had got a formal negative answer. Also we were not particularly motivated as we relied on the use of the much cheaper Swedish belt.

However, considering that such a belt could possibly solve the problems encountered, we discussed again this question with the manufacturer which finally proposed us a way of making a long belt from an interwoven spliced cotton carcass with same electrical characteristics as usually and with probably sufficient mechanical tightness. Because such a belt would be quite expensive a short belt of this type has been first ordered for testing it in the pilot machine.

An other solution was to modify the geometry of the system according to the above analysis. Compromise has been done between the best decoupling (small distance between up and down runs of the belt), sufficient guiding and driving pulley diameters, resulting in the new arrangement of Fig. 1 with Ø 150 mm driving pulleys and only one over four guide roller kept with a decreased angle from 31° to 6°.

Test of a model arrangement very close to this one (nominal speed and rest tension, one guide roller with a 6° angle but still with 100 mm diameter) results in a serious improvement. Lifetime is much longer (five to ten times) while parasitic charge level is well reduced.

Corresponding modifications have so been realised on the real system and are operational in the Vivitron generator (Fig. 5).

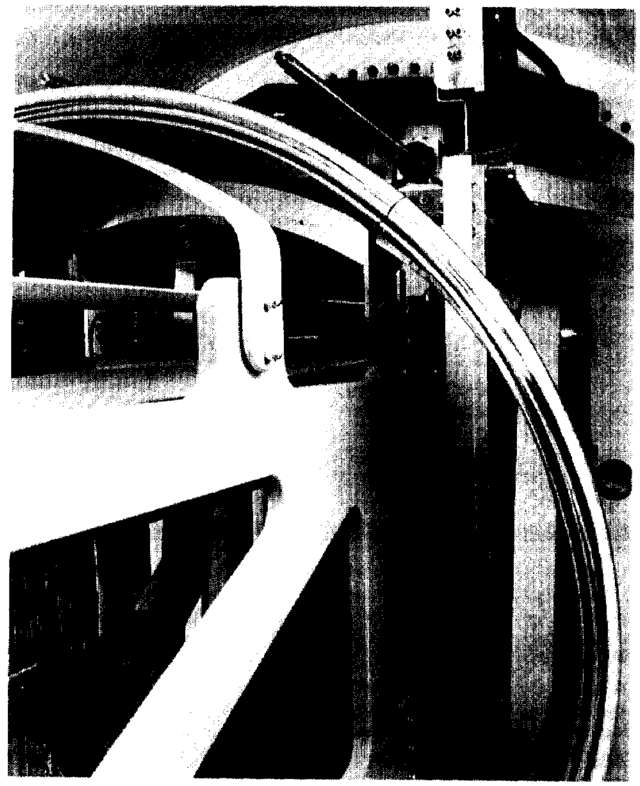


Fig. 5 View of one end station of the modified charging system showing the belt on the driving pulley and the left guide roller.

First Results with the Vivitron Charging System

The charging system for the Vivitron was first realised according to the initial design and completely assembled in November last year. Modifications above mentionned were undertaken at the beginning of the year are are achieved.

Before the completion of the Vivitron generator, only limited tests could have been done. Mechanical adjustments have so been made and running under atmospheric air with no voltage (all conducting pieces being connected to the ground) and no supplied charge has been only demonstrated together with initial and modified systems.

Both are mechanically satisfactory. Mean tracking was very easily adjusted and almost perfect with the first as it had been on the test bench. With the second one, adjustment is a bit more difficult as there is no guide roller at one end and tracking is perhaps not so perfect but still quite good as only 5 mm apart over the 50 m long axis.

On the contrary dynamic transverse motion is quite large with both arrangements. Initially with the new belt and the first geometry it was 24 mm and had been reduced to 14 mm by cutting both sides of the belt at a time while running at nominal speed. However it has become again 21 mm at one end to 25 mm at the other with the modified geometry.

Induced vibrations levels are evenly low.

With the four guide rollers arrangement, parasitic charge level was very high - several hundreds of µA at the very beginning - with the new belt, as already observed in the pilot machine. Residual level after some hours was ~200 µA and was reduced to ~80 µA during the first try with only one roller.

In conclusion mechanical behaviour of the charging system is quite satisfactory. Observed defects (mainly dynamical transverse motion) are due to the belt itself.

Electrical behaviour has not been explored yet. Complete tests with SF6 pressure are anticipated in September this year.

References

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