

HIGH-VOLTAGE POWER CONVERTERS FEEDING THE ION PUMPS OF THE LEP VACUUM SYSTEM

R. Genand, A. Delizée

CERN, SL Division, 1211 Geneva 23, Switzerland

Abstract

The LEP vacuum system requires, in addition to other pumping systems, a total quantity of about 1400 ion pumps to reach the operational performance of 1 to 2.10^{-9} Pa. In general, six ion pumps are electrically connected in parallel. They are supplied by one power converter of 5.6 kV and of 225 mA short-circuit current. This report describes the design and the series production evaluation of 400 power converters as well as the operational results obtained since June 1989. Details are also given on the simulation of transients in short-circuit operational mode of ion pumps, on the automatic test system and on the reliability required.

Introduction

The low pressure pumping systems of the Large Electron Positron collider (LEP) is achieved by using sputter ion pumps of 400 l/s in the radio-frequency accelerating regions and of 40 l/s in the other parts. The LEP vacuum system is housed in an underground ring tunnel of approximately 27 km circumference, divided into 127 sectors of 474 m length maximum. The ion pumps of each sector are fed by power converters located

Power converters characteristics and circuit diagram

The output curve of average voltage and current imposed by the characteristics of the ion pump should be within the following values : $I \leq 0.1$ mA, $V = 5.6$ kV $\pm 2\%$, 1 mA / 5.3 kV $\pm 5\%$, 10 mA / 4.5 kV $\pm 10\%$, 100 mA / 3.2 kV $+10\%$ -5% , short-circuit current 0.225 A $\pm 7\%$. The ripple voltage should be below 30% at 100 mA. The power converter should be able to operate in permanent output short-circuit mode. To fulfil the requirements of reliability and robustness, a circuit topology was chosen composed of a special high-voltage transformer equipped with a magnetic shunt, easily adjustable to get the imposed load curve and a voltage doubler with filter (Fig. 1). A shielded $50\ \Omega$ coaxial cable (length : 2 km max.) links each power converter to a maximum of 8 derivation boxes (normally 6 units). Each ion pump is fed via a 50 k Ω resistive coaxial cable (length : 10 m); this cabling arrangement keeps an acceptable pumping speed with 5 ion pumps in operation should one unit be short-circuited

A facility for total current ion pump reading (range $10\ \mu\text{A}$ - 0.225 A) or equivalent pressure reading is incorporated. The indication of a "good vacuum" should also be displayed showing that; the output current is

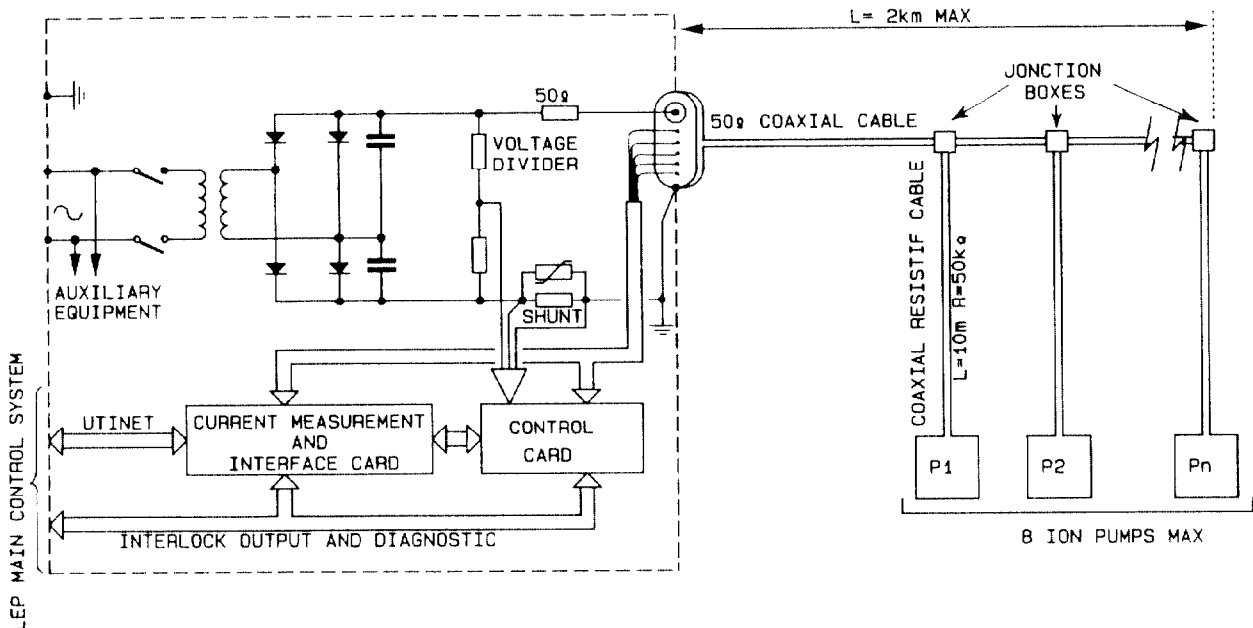


Fig. 1 Power Circuit Diagram

at the bottom of each pit [1]. One power converter can feed either up to eight pumps of 40 l/s connected in parallel or one pump of 400 l/s. They should be highly reliable, robust, remotely controllable (including their individual current measurements) and cheap.

below the preset value; the output voltage is correctly set and the high-voltage circuit is in a safe position. An interlock will switch off the power converter when the output exceeds a preset level and can be inhibited to accept operation under high-pressure mode. All the functions

mentioned above and all the communications (including remote control) with the local central computer unit are made by the current measurement interface card and the control card.

Circuit simulation

The program Script [2] was used to simulate the power circuit. The design characteristics of the HV transformer are mainly given by the height of the units (7 inches max.) and are summarized as follows : induction 1 T max., iron cross-section 20 cm² max., two coils primary and two coils secondary, possibility of a magnetic shunt of 20 mm max. assembled between primary and secondary coils, leakage inductance of 2.08 H primary and 190 H secondary. The linking coaxial cables (50 Ω) were modeled as LC distributed networks.

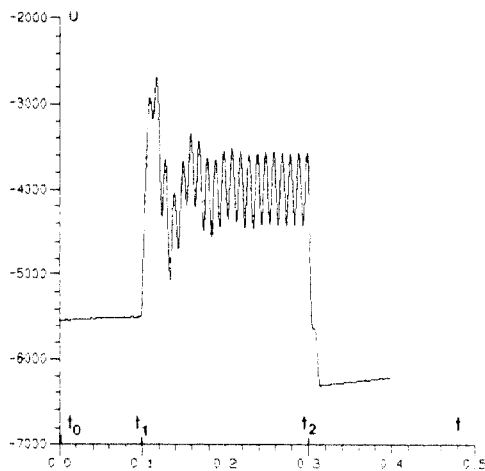


Fig. 2 Output Voltage Waveform

Fig. 2 shows the waveform : normal operation (t_0 to t_1), one of 6 ion pumps short-circuited (t_1 to t_2) and normal operation at no-load ($> t_2$). The mean residual output voltage in short-circuit mode is still 70% of the no-load voltage. Back to normal operation ($> t_2$), the overshoot is of 13%. The simulation value with two ion pumps short-circuited is 60% of the no-load voltage and of 42% with four units shorted.

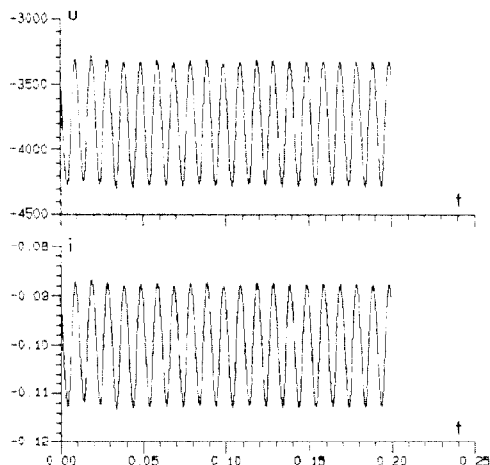


Fig. 3 Current and Output Voltage Waveforms

Fig. 3 shows the current and output voltage waveforms for a mean output current of 0.1 A; the simulated ripple voltage is 17%. The simulation value of the mean short-circuit current is 0.225 A.

Prototype and series production

The prototype was designed by CERN and was used as a model for the series production by industry. An open view of the power converter, with the high-voltage shield removed is given on Fig. 4.

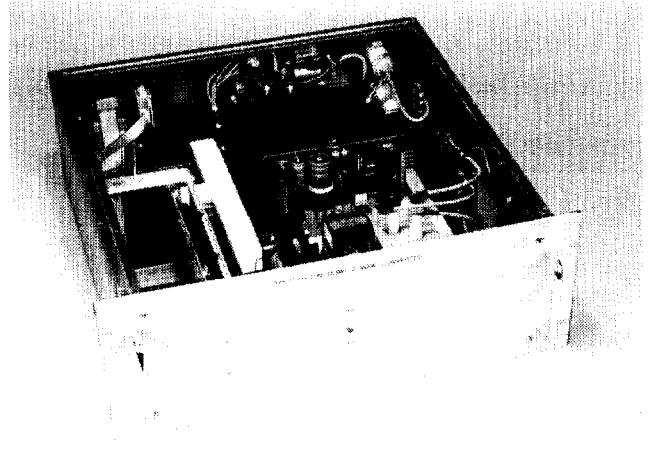


Fig. 4 Power Converter

The transformer has a core of grain orientated steel laminations and HV coils are encapsulated in polyurethan (insulation tests : 12 kV r.m.s.). Selected avalanche diodes (recovery charge, avalanche voltage) are connected in series, without RC equalizing networks. Filter capacitors, paper type and mineral oil impregnant, are housed in a tank (tested at 15 kV under 70% relative humidity and 70°C). The HV connector is of a compact type with high-voltage cones (tested at 30 kV D.C. under 70% relative humidity). All the cables and components are halogen free. The electronic cards are mounted in a crate and the adjustments can be done during operation of the power converter.

For getting the output values according to the imposed tolerances, the magnetic shunt should be between 18 to 20 mm thick with an air gap of 1.04 mm. The magnetic steel sheets should be of 0.5 or 0.35 mm thick. The two millimeters thickness difference of the magnetic shunt can compensate all the slight differences of the 400 magnetic cores.

The coupling between primaries and secondaries coils is increased either by enlarging the air gap or reducing the cross section of the shunt. Consequently, the short-circuit current and the output voltage are increased

Fig. 5 shows the load curve for the magnetic shunt of 19.25 mm and 20.3 mm thick.

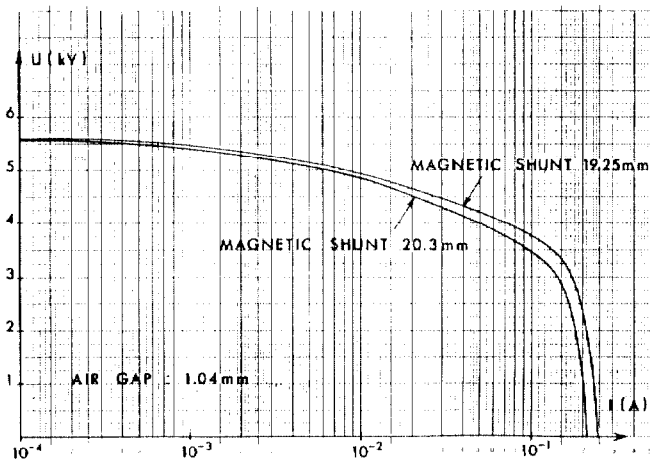
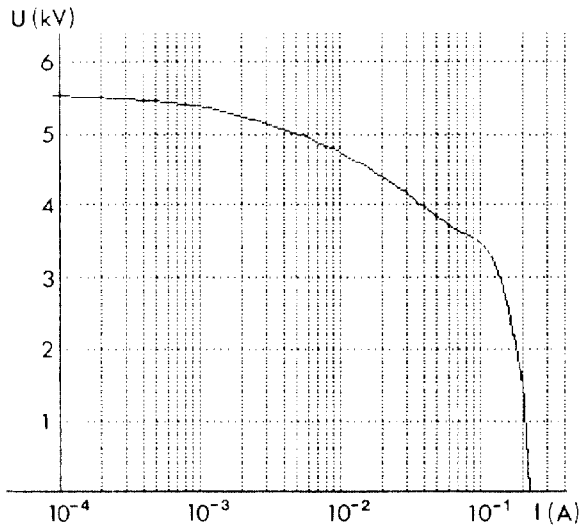


Fig. 5 Output Voltage with two Magnetic Shunts

The prototype performed successfully the long-term tests simulating the working constraint of the environment : relative humidity 70%, temperature 45°C max and dusts mainly due to concrete. Eight power converters equip a standard rack; tests with all the units shorted gave a hot-spot temperature of 70°C max.

For the series production, all the tests were performed with a variable high-voltage load and with an automatic test bench equipped with microprocessors for calibrating the load curve and for presetting the digital and analogic signals of the electronic card.



** TENSION A VIDE = 5.56 KV
 ** TENSION DE SORTIE POUR I = 1 MA : 5.38 KV
 ** TENSION DE SORTIE POUR I = 10 MA : 4.74 KV
 ** TENSION DE SORTIE POUR I = 100 MA : 3.47 KV
 ** COURANT DE COURT-CIRCUIT = 226.5 MA

Fig. 6 Plotted Load Curve

The plotted load curve is given on the above figure; numerical values insure that measurements are within the tolerances. The dispersion of the results among the 400 units was : short-circuit current +1% -7%, mean voltage at 10 mA, +5% -2% and mean no-load voltage +0.5% -2%.

LEP Operational Results

The first power converter was installed at the bottom of the LEP pit on February 1988. The installation of the other units was realized according to the schedule of the bake-out of the vacuum chambers. All the 400 power converters were in operation since May 1989 (24/24 Hrs duty). At the beginning of the power converters operation, these were submitted to particular difficult conditions such as a large quantity of concrete dust combined with a high level of ambient humidity.

To date, only three power converters were not working properly (with no perturbation of the LEP circulating beams), which gives a failure rate on the series of 0.75%. These first operational results give us confidence of our design for the long term operation and for the expected life of at least ten years.

References

- [1] P. Strubin, Controls for the vacuum system of LEP, CERN/LEP-VA/86-31.
- [3] F. Bordry, Synthèse des Méthodes de Simulation des Convertisseurs Statiques, Thèse de Docteur Es-Science, Toulouse, December 1985.