THE FIRST OPERATIONAL EXPERIENCE OF THE LEP POWER CONVERTER SYSTEMS

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Abstract

The LEP Power Converters have achieved excellent performance from the very first day of the start-up of the machine. This was reached despite the extremely short period for system tests on their real loads. These tests, which included set-ups through the central control system, were followed immediately by the start-up of LEP with beam. The very good performance and reliability of the converter systems contributed positively to the rapid progress of the LEP commissioning. Details are given about the individual testing of the converters for the magnet system, the RF klystrons and the sputter-ion pumps of the vacuum system. The first months of LEP operation allow a rapid evaluation of performance and reliability. Operational aspects are also discussed.

Introduction

The first operational experience, based on six months of LEP running in 1989 and three months in 1990, has been excellent, It has shown that a high level of reliability was obtained and that the full performance was achieved.

The power converters for LEP Main Ring have been described in detail in previous papers. As a summary the following information is given on the three main systems.

- Power converters for the magnet system : 770 units.

Power :	0.6 kW to 7000 kW
Current :	2.5 A to 31.000 A
Current range (max.) :	1:10.000
Stability (max.) :	$\pm 5 \cdot 10^{-5}$.

- Power converters for RF klystrons : 8 units

Power :	4 MW
Current :	40 A
Voltage :	100 kV.

- Power converters for sputter ion pumps : 380 new units plus 280 old units

Voltage :	5,2 kV
Current :	0,25 A (into short-circuit).

Total power throughput	57 MW
Number of electronic modules	11.000
Number of interlocks	> 10.000
Total number of components	>1.600.000
of which integrated circuits	> 40%
Electrical joints	>7.400.000
Expected optimistic MTBF of each converter	50.000 hrs
Expected optimistic MTBF of the converter system for magnet	50 hrs

Throughout the entire LEP project there had been two equally important aims : achievement of the performance and reliability. These points were, of course, already taken into account at the design stage and merited all our attention during the construction and commissioning phases.

The commissioning of power converters

The first months of 1989 were mainly devoted to individual tests at CERN of power converters for the three main systems. During the production stage in industry all the thousands of sub-assemblies and later the complete assemblies had undergone rigorous testing, to assure strict compliance with the CERN specification. At CERN, tests were carried out on the complete power converters on dummy loads.

Automatic test systems checked through all the functions of the converters in a systematic way. All detected defects were analysed and repaired. Whenever possible, full power twenty-four hour runs were carried out on dummy loads. Additional running hours were accumulated in order to weed out early failures.

Special attention was paid to all high precision components, vitally important for meeting the tight (10^{-5}) tolerances of the current controlled converters. They were the DAC's (digital-to-analogue converters), ADC's (analogue-to-digital converters), and DCCT's (d.c. current transformers). All of them were thoroughly tested. A particular problem were the DAC's which showed a long term drift traced down to impurities of the plastic encapsulation. At a later stage inconsistent burn-in procedure by the manufacturer caused further concern.

For the 100 kV, 40 A, 4 MW converters for the RF klystrons, a special test stand including an aqueous dummy load for 4 MW and spark gaps had been built. This set-up allowed to test these very special converters at full power and realistic operating conditions over extended period of time.

In a continuous process, the power converters passed through the test area and were consequently installed in the eight surface buildings, one experimental hall and four underground caverns. They were connected to the mains and to the real loads. Testing was continued when they became available. During such periods, access to certain zones of the tunnel was prohibited for reasons of personnel safety and cooling water and interlock systems had to be operational.

Initially, the date of mid-July 1989 had been defined as the end of LEP installation. No further details of the time scale for system tests and preparation of LEP for the first injection of beam were given. After a certain time, attitudes changed and mid-July became the starting date of LEP running-in. Soon afterwards, the 14th of July was declared the official day when the first beam was injected into LEP. Indeed, reality surpassed fiction : the first positrons entered LEP on the 13th of July and within a few hours went around the ring, i.e. 27 km.

With this in mind, it is easy to imagine that April to July were very hectic months. During these four months, two periods of two weeks each were initially planned for testing the power converters feeding the chains of the main bending magnets, the focusing and defocusing quadrupoles covering the 27 km of the ring. This total of four weeks shrunk rapidly and at the end, barely two days for each period were available which had even to be shared with many other groups. As a result only a limited number of tests could be carried out for all 770 power converters. Among them, a full power run, calibrations, some stability checks, and last but not least a ramping test. Some of them could be carried out with the final software through the central control system from the Prévessin control room.

The running-in of LEP

On 13th of July, all power converters were set at their theoretical value for a beam energy of 20 GeV/c. The injected beam had its energy defined by the SPS, the last in the long chain of injector machines. The positrons went around from octant to octant. The only beam observation available were luminescent screens which permitted the determination of the beam positron at the beginning and at the end of each octant (3.4 km long). Few hours later, the beam had been threaded through the 27 km of LEP and was seen in the centre of the last screen. One single correction had been necessary to achieve that formidable result.

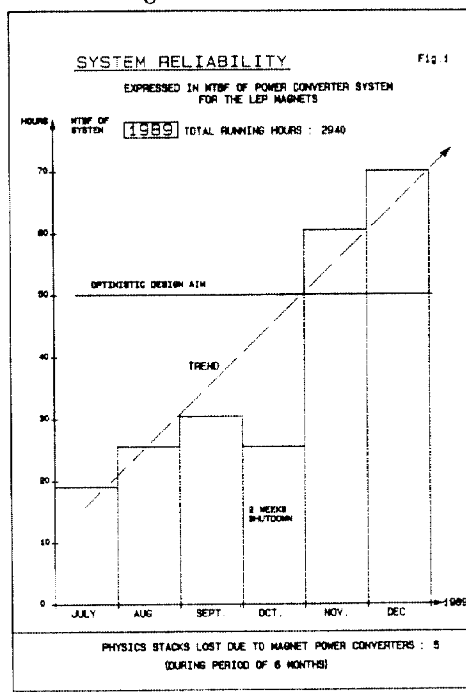
This extraordinary performance showed that a remarkable absolute precision had been achieved. This did not only include the SPS energy measurement, but also the complete period of LEP magnet development and production, including all d.c. current calibrations over a wide variety of converters and over many years.

The LEP running-in phase has also been well prepared on the man-power side by the power converter group. Not only all its members were available, but a particular operational crew had been set up and trained. Their in-depth knowledge of the overall system assured professional assistance to the engineers-in-charge.

Henceforth a remarkable reliability of the converter equipment was observed. Breakdowns were rare and most of the incidents were on the interfaces to other systems such as controls, its software and cooling water.

Physics run

On the 13th of August, exactly one month after the first injection, the first pilot run for physics started. This was followed by a regular pattern of physics runs and machine development session, interrupted by scheduled shutdowns. Reliability of the power converter system was very good. During the six months of LEP operation in 1989, only five physics stacks were lost due to power converter faults and one during the first three months of 1990 (March to June). The steady increase of the mean time to failure of the power converters of the magnet system for 1989 is plotted in Fig. 1. After the start-up in mid- March '90, the figures of 1989 were quickly surpassed. Our very optimistic aim of 50 hours of MTBF for the complete system was already reached in Autumn 1989 and later exceeded. The mean time to repair was kept low due to the rapid intervention of the well trained converter specialists. The extensive diagnostic system incorporated in the local intelligence allowed good fault analysis. In most cases an exchange of modules cured the fault.



The few systematic faults (hardware and software) were eliminated during the first months such that later in 1989, only random faults occurred.

The short-term stability ($\pm 5 \cdot 10^{-5}$ of maximum current over four hours in the most demanding case) was met. With stable mains and constant building temperature, the stability is considerably better (approximately 10 ppm). The short-term reproducibility from run to run is within the short-term stability limit. Long-term stability (over months) of the DAC's needs further investigation.

First conclusions

The nine months of LEP running (July to December 1989 and March to June 1990) have shown that the machine has a performant and reliable power converter system. The massive adoption of new technologies has been a success. The conception of the overall system has proven its flexibility. This allowed to cope with many problems popping up at the last moment. Reliability as well as repairability is very good. The choices made show their promises for future machines with even higher requirements on reliability.

Acknowledgement

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