THE OPERATIONAL STATUS AND UPGRADES OF THE ELETTRA LINAC

C.J. Bocchetta, G. D'Auria, D. Daclon, P. Del Giusto, M. Milloch, A. Milocco, A. Pozzer, C. Rossi, A. Tomicich, Sincrotrone Trieste, Italy

Abstract

The ELETTRA Linac has been in operation since 1992 and from June 1994 has been working under Sincrotrone Trieste's responsibility. During these years plant data have been collected and their analysis allows some considerations about the long term operating conditions and costs. An improved reliability of the machine operation has also been achieved by a constant monitoring and adjusting of the most critical parameters. Longer lifetime of crucial and costly devices, like klystrons and thyratrons, have been gained by the implementation of new sub-systems and a proper setting of the operating parameters.

In this paper the operation and the present upgrading program of the machine are presented together with the possible future developments.

1 INTRODUCTION

The ELETTRA Linac injector has already been described elsewhere in detail [1,2]. Up to the beginning of 1997 the Linac was operated also in connection with different applications (test of the FEL operating mode [3], Optical Transition Radiation measurements [4]). From March 1997 the operation has been entirely dedicated to the injection into the ELETTRA storage ring, summing around 3000 hours of operation in 1997 and 1150 in the first four months of 1998.

In the 1998 planning for the ELETTRA operation, a more intense schedule has been considered for the injector, about 3500 hours will be the Linac time dedicated to storage ring operation, based on longer operation runs, from four to six weeks, and fewer shutdowns; the further demand for higher reliability implies a more careful monitoring of the Linac operating conditions and the setting up of preventive maintenance procedures.

Moreover, the future developments planned for ELETTRA also ask for a possible solution to the Storage Ring full energy injection; for this purpose a possible increase of the Linac beam energy, up to 2.0 to 2.5 GeV, is now under consideration.

2 OPERATIONAL STATISTICS

During all the ELETTRA user dedicated and machine physics runs of 1997, as well as in the first two runs of 1998, the Linac downtime has been below 3% of the operating time, with only the exception of RUN 42, when it increased to almost 23% due to a 60 hours stop of the Linac caused by a SF6 leak in the RF dispatching system on the 100 MeV part of the injector, which is pressurised at 3 bar. Even if we include this exceptional event in our analysis, it is possible to see that the average downtime per run is around 3.8%, which is almost 2% less than in the past year (1996); excluding the SF6 leak downtime, the average downtime goes down to 1.6% (Fig.1).

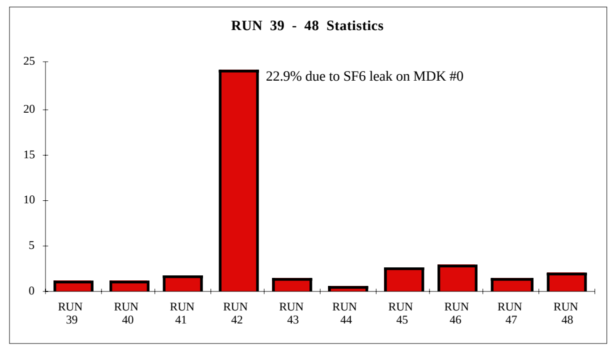

Figure 1: Downtime statistics in the 1997 operation runs.

When considering the fault statistics from the main Linac sub-systems (Fig.2), 60% of the whole downtime in 1997 is represented by the SF6 leak of RUN 42, after this the main source of Linac downtime still comes, as in the past years, from the microprocessor control system. The modulator system downtime is essentially due to failures on recirculating diodes and electronic components mounted on the de-q'ing circuitry, which can be assigned mainly to an expected ageing of the system; the same can be assumed for the HV and beam focusing power supply faults.

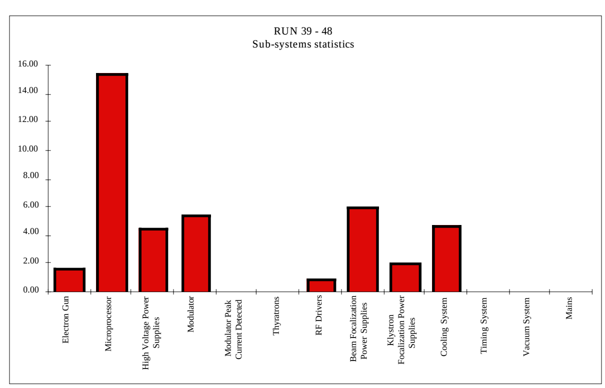

Figure 2: Downtime statistics by subsystem. The run 42 SF6 leak has been excluded to highlight the other fault sources.

Histogram in Fig.3 shows the relative variations in the percent downtime for sub-systems for different years: the general tendency is towards a reduction of the downtime. This histogram is particularly helpful in suggesting which faulty subsystems have to be substituted with spares to eliminate the source of Linac failure.

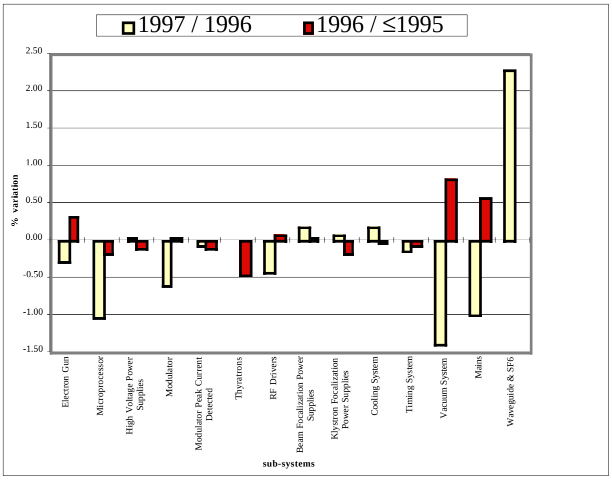

Figure 3: Comparative yearly variations of sub-system downtime.

3 CRITICAL COMPONENTS MANAGEMENT

During 1997 and in the first four months of '98, two TH2132A Klystron tubes have been replaced on the RF plants, each of them having completed roughly 18000 hours of operation. We have observed that for both tubes, the replacements were not due to the expected μ–perveance reduction, but to a tube failure in withstanding the anodic HV pulse. This effect could be explained by a slow vaporization of cathode fragments on the anodic surface during operation. The remaining six tubes have now reached roughly 20000 operating hours and are routinely operated between 36 to 38 MW, with 3 to 3.5 μsec RF pulses.

In the same period, we have also replaced two EEV CX 1536 Thyratrons, with more or less the same operating hours of the Klystrons, that were at the end of their life-time: no further possibilities for reservoir adjustments. Generally during the machine shutdowns the main operating parameters for both Klystrons and Thyratrons are checked and re-adjusted at proper setting values to follow with component ageing and to try to prevent machine down time during operation.

Concerning the solid state RF amplifiers, used as Klystron drivers, during the above mentioned period we mainly suffered problems from the ageing of many electronic components. Nevertheless, to gain in reliability, in '97 we installed and tested on the plants two new pre-amplifiers developed in collaboration with an UK company, that can supply RF pulses up to 10 μsec, 300W, with excellent amplitude and phase stability (≤ 0.1 dB; ≤ 1°).

Furthermore, at the beginning of '98, one TH 20279D ceramic window has been replaced on the first Sleded RF plant, because of problems with arcs.

3.1 Operational costs

A crude estimate of the machine operational costs has been based on a 3500 to 4000 hours/year operation. Considering that the average life-time of the main critical components, like Klystrons and Thyratrons, range from 20000 to 25000 hours, or even more, a complete set of these components could be used for roughly six years. In the following table a cost estimation (in K$) for six years operation is reported.

Klystrons		760
Thyratrons		140
Waveguide components		70
Plant maintenance		360
Power consumption		400
	Total	1730

The above estimate takes into account the need to keep available in the laboratory spares of main strategic components, which have a long delivery time, for a fast replacement in case of failure. The plant maintenance estimate has been based on the last five years of operation together with the expected ageing of the plants. Concerning the power consumption, it has been measured that the machine requirements, at its full energy (1.1 GeV), come to roughly 300 kW.

4 NEW SUB-SYSTEM INSTALLATIONS

As already mentioned [2] new heating chassis for the klystron and thyratrons have been designed and tested, together with a new interlock system.

The new heating chassis is a modular power supply system which also integrates in the same unit the control and interlock functions as well; it has been equipped with a non linear resistor allowing a soft start for the delivered power, and a 80% intermediate stage to fully operate the plant in less than 5 minutes after switching on from a stand-by condition. All the measurements and information about the status of the system can be transmitted or memorized and simple programmable on/off sequences are achievable.

The interlock system will consist of a modular hardwired relay assembly installed on each modulator plant; the plants will be connected to each other with a 24 V_{DC} bus to share the information. A four level interlock system has been employed, with a local point to point intervention capability and a distributed level to level interlock action. The prototype relay chassis has been successfully tested in the laboratory and now is being assembled on the pilot plant of the new control system.

The major improvements, which are presently part of a funded project, regard the installation on power plant #1 of a prototype of the future Linac control system [5], including all the new hardware assemblies reported before.

Moreover a new high voltage distribution system for the sputter ion pumps mounted on the accelerating sections and waveguides has been already assembled and tested; the new system is now operating for tests on a plant of the machine allowing vacuum monitoring as well as the control of all the vacuum valves installed on the same plant.

A new dedicated HV power supply, remote controlled via RS 232, has also been installed on each modulator; these new constant current power supplies will allow to operate all the modulators independently and without the need for a de-q'ing circuit.

5 FUTURE MACHINE DEVELOPMENTS

As already mentioned above, the possible future upgrading of ELETTRA asks for full energy injection in the Storage ring of up to 2.5 GeV [6], whereas the maximum reachable energy with the present injector has been fixed at no more than 1.1 to 1.15 GeV (rather than the 1.5 GeV expected from the original project).

To overcome this limitation two solutions are now under consideration:

a) the construction of a dedicated Booster Synchrotron;

b) an increase of the Linac energy up to the required levels.

Up to now the injector energy limit results from the very high electric field gradients at which the accelerating sections are operated (25 to 28 MV/m). Even if on a few sections we have reached accelerating gradients close to 30 MV/m, reasons for reliability and continuity of the operation, suggest to keep them lower.

A possible solution to increase the Linac energy comes from a partial recirculation of the beam.

A first hypothesis under investigation, a single turn beam recirculation, should give a final energy of 2.1 GeV. This will involve a recirculation in the first three long accelerating sections, without the RF pulse compression cavities, and the addition of some new accelerating units in the area already existing inside the Linac tunnel and the adjoining experimental hall.

A second hypothesis is based on a double beam recirculation to bring the beam energy up to 2.6 GeV.

6 CONCLUSIONS

The good reliability and the simple cost analysis which have been presented show that the ELETTRA injector Linac fits well with the present operational requirements of the Storage Ring. The current hardware upgrades will further improve the injector reliability with an expected reduction in future maintenance efforts as well as manpower required for the operation.

As a future development, the beam recirculation option looks attractive for many aspects:

i) it could be implemented with a limited effort, without interfering with the normal operation of the Storage Ring;

ii) it may be the cheapest solution to have a full energy injection in ELETTRA;

REFERENCES

[1] D. Tronc et al., "The Elettra 1.5 GeV Electron Injector", IEEE Particle Accelerator Conference Proceedings, San Francisco, USA, May 1991.

[2] G. D'Auria, et al., “Operation and Status of the ELETTRA Injector Linac”, PAC’97, Vancouver 1997.

[3] G. D'Auria, et al., “Operation of the 100 MeV Pre-Injector Linac of ELETTRA in the FEL Mode”, EPAC’96, Sitges, June 1996.

[4] D. Giove et al., "Optical Transition Radiation Measurements on the ELETTRA Linac", PAC’97, Vancouver 1997.

[5] L. Bulfone et al., "Design and Development of a New Control System for the ELETTRA Linac”, EPAC’96, Sitges, June 1996.

[6] C.J. Bocchetta, R.P. Walker, these proceedings.