OPERATION AND STATUS OF THE ELETTRA INJECTOR LINAC

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Abstract
The injector Linac of the ELETTRA Storage Ring has been operating since 1993 providing a 1.0 GeV electron beam. Since that time many technical problems have been solved to increase the machine reliability by progressively upgrading all the machine sub-assemblies. Here the machine operation and the status of the upgrading program are described.

1 INTRODUCTION

Starting from 1993 the ELETTRA Linac is routinely running as injector for the Synchrotron Light facility ELETTRA, providing a 1.0 GeV electron beam. The machine is made up of two different parts: a 100 MeV preinjector and a booster Linac up to 1.0 GeV; a complete description of the whole machine can be found in [1,2]. Even if the Linac is mainly used as the storage ring injector, in the last few years additional scientific activities, have been considered, i.e. an IR/FIR FEL experiment set-up [3], as well as the installation of a movable OTR (Optical Transition Radiation) measurement station [4,5].

In the past year the machine was operated for roughly 3500 hours/year most of which, 90%, for injection and maintenance, while the remaining 10% has been used for the upgrading program and new activities.

In the same period, to improve the overall efficiency of the machine, the following upgradings have been undertaken[6]:

a) improving the poor reliability of some critical machine sub-assemblies via a re-design of the timing system, the control and interlock system ecc;
b) because the booster Linac is SLED equipped, the RF power and the pulse length from the klystron tubes have been set to avoid to exceed a gradient of 24÷26 MV/m on the accelerating waveguides which up to now seems to be a reliable value for convenient operation;
c) constant monitoring procedure for the klystron operating parameters and some other critical components has been implemented to prevent sudden replacements with consequent long machine downtime.

2 OPERATION

The ELETTRA Storage Ring is generally run on a three/four week basis followed respectively by one/two week shutdowns with roughly 82% of the total beam time for Users and the remaining for machine studies. Except for the machine study shifts, where the Linac is continuously kept in operation 24 hours/day, Storage Ring injection requires the Linac once per day in the morning with typically 1÷2 mA/sec injection rate. After injection the Linac is kept in operation for plant monitoring, machine optimization and service; FEL and OTR operations are generally implemented after the daily injection. The Linac can also be operated in single bunch mode, with 2 ns current pulses at 10 Hz, but for the present the storage ring is operated in multibunch mode. The main parameters for the injection and for the FEL operations are listed in the table below:

Measured parameters:	Injection	FEL
Operating Energy	1.0 GeV	30 MeV
Maximum Energy	1.1 GeV	75 MeV
Macropulse width	2 or 10÷150 ns	6 μsec
Macropulse repet. rate	10 Hz	10 Hz
Current	up to 30mA @ 70ns	> 100 mA @ 6 μsec
Energy spread	± 0.5 %	± 0.5%
Micropulse pattern	Single/Multi bunch	2 ns @ 25 MHz p.r.r.
Emittance	not measured	3.38 p mm mrad

Table 1: Injection and FEL operating parameters.

Table 2 reports some operating parameters for the RF plants together with the obtained energy gain per accelerating section. The energy gain of the pre-injector has been kept lower than the maximum achievable to increase the plant safety margin with a consequent improvement in reliability. The maximum reachable energy from the injector, without compromising the efficiency, is 1.08÷1.10 GeV, we have also operated at energies up to 1.2 GeV but in this case the higher electric field inside the accelerating structures causes many RF field breakdowns with an unacceptable increase in the machine downtime.

RF Plant	Klys. Filam. hours	RF Power (MW)	RF Pulse lenght (μs)	Energy gain (MeV)
MDK0	15247	38	2.0	85
MDK1	15893	41	2.7	134
MDK2	15386	43	3.0	152
MDK3	15656	42	2.7	145
MDK4	14975	42	2.4	141
MDK5	15115	43	3.0	150
MDK6	14407	42	3.2	156
MDK7	14305	42	2.5	139

Table 2: RF plant operation.

As is reported in the table 2, up to now we have operated each RF plant for roughly 15000 hours and at the the beginning of '97 we have also started the klystron replacement program. The first Thomson TH 2132A tube has been replaced in February '97 on the pre-injector RF plant MDK0; the tube has been kept operating for 14645 hours in approximately 6 years at 40 MW/3µsec power level. It is necessary to point out that the klystron failure was identified in the electric field breakdown inside the tube probably due to slow accumulation of cathode fragments on the anode surface during operation and that no considerable decrease in the microperveance was observed during the long operating period. During '95 to '96 we have also substituted five EEV CX 1536X thyratron tubes with more than a mean 10000 hours of operation.

The histograms in Fig.1 and Fig.2 give respectively the percentage per run of the Linac downtime during '96 as % of the total running hours, and the Linac sub-systems downtime statistics as percentage of the total Linac downtime.

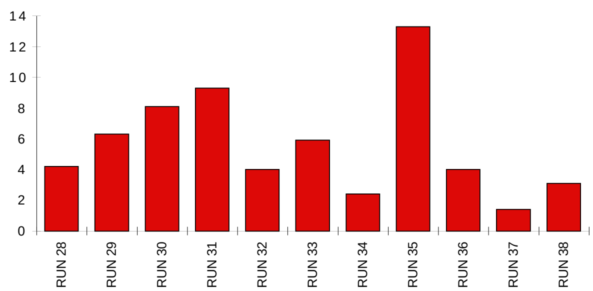

Figure 1: Linac overall downtime statistics during 1996.

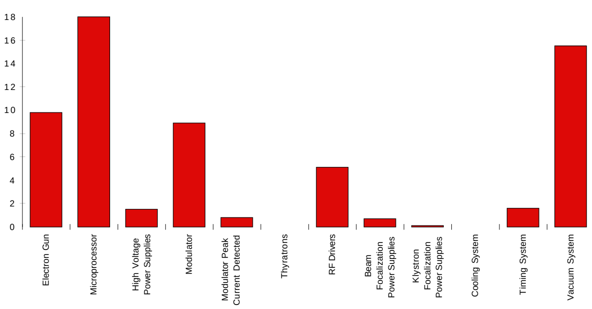

Figure 2: Linac subsystems downtime statistics (run 28÷38) in percentage of the total machine downtime.

It is necessary to point out that the anomalous 13.3% value of the run 35 results from a vacuum leak suffered by the last accelerating section (11.0% downtime) and that during run 30 we had serious problems on the electron gun (7.8% downtime, for the replacement of the cathode). Anyway, it seems reasonable to assume a mean value of 6 to 7 %, for the downtime of the machine during the whole '96. Looking at Fig.2 and taking into account the random contribution due to the section seven vacuum leak, and to the cathode replacement, it is necessary to point out that the main fault source still remains the machine control system. If we include the general service faults (electricity, water ecc.), the overall Linac contribution to the ELETTRA beam downtime in '96 goes up to roughly 9%.

3 MACHINE UPGRADING PROGRAM STATUS

As already said, in order to improve the low reliability of the machine, a re-design of some sub-systems has been undertaken.

The New Linac Timing System: to avoid suffering from problems deriving from trigger instabilities, a prototype of the new Linac timing system has been realized and tested on the field [7]. It is based on a local reference clock from a 50 MHz signal, synchronous to the ELETTRA master oscillator. The five kinds of trigger given to each of the eight RF plants are supplied by delay boards developed at Sincrotrone Trieste and housed in a VXI crate for noise immunity; they have fully programmable trigger outputs which can be delayed from 10ns up to 1.2ms, 10ns/step and each one can be independently interlocked to an external trigger. An in-phase synchronization with the start injection signal will allow a real bucket by bucket storage ring filling. At the end of '96 the first trigger board has been successfully tested on the machine and we plan to implement the whole system during '97.

The New Control and Interlock System: at present the control system operates with a centralized architecture and no special care had been given by the supplier to the signal distribution system as well as grounding and noise problems. The new control system [8] will be built with a spread architecture: all the machine will be divided into 9 blocks, which we will call plants and each plant will have an intelligent local processing unit where the low level software manages the local processes and talks with the high level software running on the workstations of the control desk, see Fig.3. The goal is to have a modular system keeping all the signals as close as possible to the related plant to prevent noise propagation and grounding interference between different plants. Up to now several prototype boards have been developed and are under testing, i.e. a fast sample/hold board for pulsed signals, a conversion board V/F, RF detecting boards, a programmable trigger board for the acquisition of pulsed signals out of the noise region, etc.; Fig.4 gives a block diagram of the analog signal acquisition layout. We plan to assembly a prototype of a complete VME acquisition crate on a plant before the end of this year. The interlock system, made up of a local relay chassis per plant, is now being assembled and we hope will be ready to start the tests on the first chassis before August.

RF plant upgrading: for the RF modulators we have completely developed a new heating chassis, completely integrated with the new control and interlock systems, for both klystrons and thyratrons; it allows to keep the filament heating currents at 80% of the nominal values during the machine stand-by to get both an extended tube life time and a very fast machine restart if necessary.

Moreover, a new pulsed 300W 3GHz RF solid state preamplifier for the klystrons has been developed in collaboration with Milmega LTD, UK and the first prototype is at present successfully running on an RF plant.

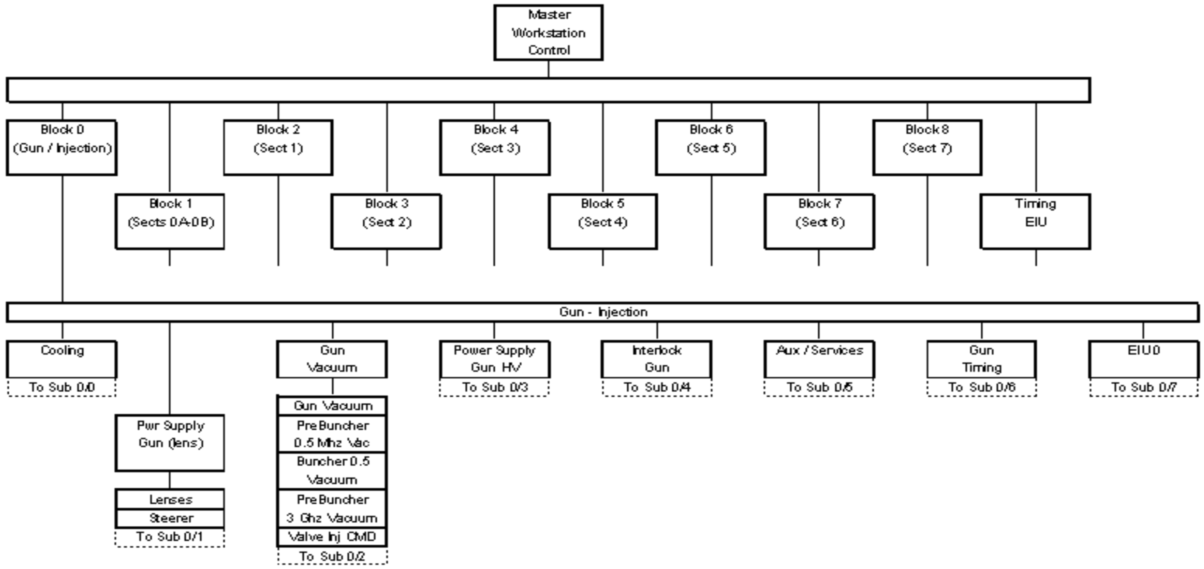

Figure: 3 Block diagram of the new machine control system with an exploded view of the block Ø.

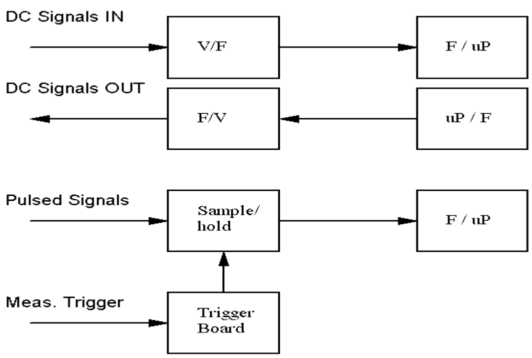

Figure 4: Layout of the analog signals acquisition scheme with voltage/frequency converters.

4 CONCLUSIONS

In the last two years, an intense activity program has been carried out on the ELETTRA Injector Linac to assure a reliable routine operation of the machine. The operating statistics for '96 show that the overall machine downtime has been kept inside an acceptable value (less than 10%) even before the full upgrading of the machine. By the first part of '98 we expect to implement the new control and interlock systems and thereafter we plan to set to work on the machine diagnostics for fast beam optimization. Moreover in the future we also intend to stimulate a growth of other scientific activities which can be carried out in a time sharing basis with ring injection.

REFERENCES

[1] C. Bourat et al., "The 100 MeV Preinjector for the Trieste Synchrotron" (IEEE Particle Accelerator Conference Proceedings, Chicago, USA, March 1989).

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

[3] R.P. Walker et al., "The FERMI FEL Project at Trieste", Nucl. Instr. & Meth. Vol. A 375, p. 252 (1996).

[4] C. Rossi et al., "A new OTR Based Diagnostic System for the Trieste Linac Injector of ELETTRA", this conference.

[5] D. Giove et al., "Optical Transition Radiation Measurements on the ELETTRA Linac", this conference.

[6] G. D'Auria et al., "The Elettra Injector Linac upgrading program", European Particle Accelerator Conference, Sitges, June 1996.

[7] M. Ferianis et al., "The New Timing System for the ELETTRA Linac" European Particle Accelerator Conference, Sitges, June 1996.

[8] L. Bulfone et al., "Design and Development of a New Control System for the ELETTRA Linac", European Particle Accelerator Conference, Sitges, June 1996.