THE INFRASTRUCTURE FOR THE ELETTRA SINCROTRONE TRIESTE

D.Zangrando†, D.Baron, A.Buonanno, A.Galimberti, A.Martinolli, M.Miculin, D.Morelli,
Elettra Sincrotrone Trieste S.C.p.A., 34149 Basovizza, Italy

Abstract

Elettra - Sincrotrone Trieste S.C.p.A. is a multidisciplinary international laboratory, specialized in generating high quality synchrotron and free-electron laser light and applying it in materials science. The main assets of the research centre are two advanced light sources, the electron storage ring Elettra and the free-electron laser (FEL) FERMI, continuously (H24) operated supplying light of the selected "colour" and quality to more than 30 experimental stations. In this paper, we are giving an overview on the status of the infrastructure plants devoted to ensuring the operation of Elettra and FERMI machines. We will also analyse the systems that mostly have impacted on the performance of both accelerators and their downtime.

INTRODUCTION

The ELETTRA (Fig. 1) 2-2.4GeV third generation light source [1], is nearing 24 years since the start of commissioning (October '93). A full energy injector, with a circumference of 119 m, was installed 9 years ago (2008), made of a 100 MeV linac and a 2.5 GeV synchrotron, at 3 Hz repetition rate and it has been operating in top-up mode since 2010. Elettra storage ring has a circumference of 259 m and operates for a large number of hours per year - about 6.400 hours - and 78% of this time is dedicated to power the 28 experimental stations, with an efficiency (up-time) greater than 96%.

Studies are now carried out in order to replace the present storage ring with a new one (with a fixed energy of 2.0 GeV) to provide intense nano-beams in the range of VUV to X-rays for the analytical study of matter with very high spatial resolution [2]. The new storage ring lattice design has been carried out taking into account the existing storage ring tunnel, building and infrastructure including the injector, the beam-lines etc. The “white paper” was completed last year and the Conceptual Design Report (CDR) it will be this year.

FERMI [3][4][5] (fig. 1) is a user facility with FEL process based on High Gain Harmonic Generation (HGHG) scheme, making use of an external laser to seed the radiation and the first seeded lasing was observed in December 2010. It operates two FEL lines which cover the wavelength range 100 - 4 nm. The linac, the FEL buildings and the experimental hall extend for a total length of about 360 m. The underground linac tunnel has a length of about 191 m. The Undulator Hall, following the linac, has a length of about 100 m (7 m wide); the experimental hall is 62 m long and 25 m wide. Civil works were carried out in about 3 years (2007-2010).

During the construction of FERMI, Elettra could operate regularly. Elettra storage ring operations were not affected by the excavation activities carried out very closely to it. FERMI machine installation was carried out in parallel with the construction of the buildings and plants, so we could start the commissioning of the first part of the machine in April 2009.

FACILITY OVERVIEW

Elettra

Figure 2 shows the infrastructure laboratory layout. Elettra storage ring building construction started in July 1991 and in October 1993 the first beam was stored in Elettra. The planning regulations did not allow the construction of macro-structures, except for the machine building. Hence it was necessary to distribute single buildings for each function. This was not at all an economical way of civil work designing because, for instance, at least the auxiliary system buildings could have been grouped into one. Their position was decided according to the following concepts: to make pipe and cable ways as short as possible and to place the buildings with vibrating equipment at a safe distance from the storage.

From the architectural point of view, it seemed to be convenient to distribute some buildings around the machine building: on the perimeter of the storage ring building, 2 additional buildings (ES3 and ES4) were constructed and dedicated to host offices (first floor) and laboratories (ground floor), for a total of about 1150 m^2 (ES3) and 1400 m^2 (ES4) (see fig. 2). Storage ring building has a diameter of 125 m; the height of the ceiling is about 12 m. The foundation was physically separated from all others in order not to be affected by building movements due to thermal effects or wind pressure. To restrain these kinds of stress a generally rigid and heavy structure was designed taking into account that in this area the “bora” wind in winter blows at a speed of over 150 km/h. The idea of cutting the ground making a sort of trench between each foundation was totally abandoned, considering that any possible movement could have been transmitted through the lower layers of the rock, so it was decided to equip each component of the ring with its own foundation i.e. magnets were supported by a solid concrete base connected to the rock as firmly as possible. The machine and the beamlines are served by two 7.5 ton cranes. In the side of the building were positioned 2 large doors for the passage of equipment. For Elettra storage ring, the average requested electrical power is ~3.5 MW (~1.4 MW for the magnets and ~0.5 MW for RF systems).

† dino.zangrando@elettra.eu

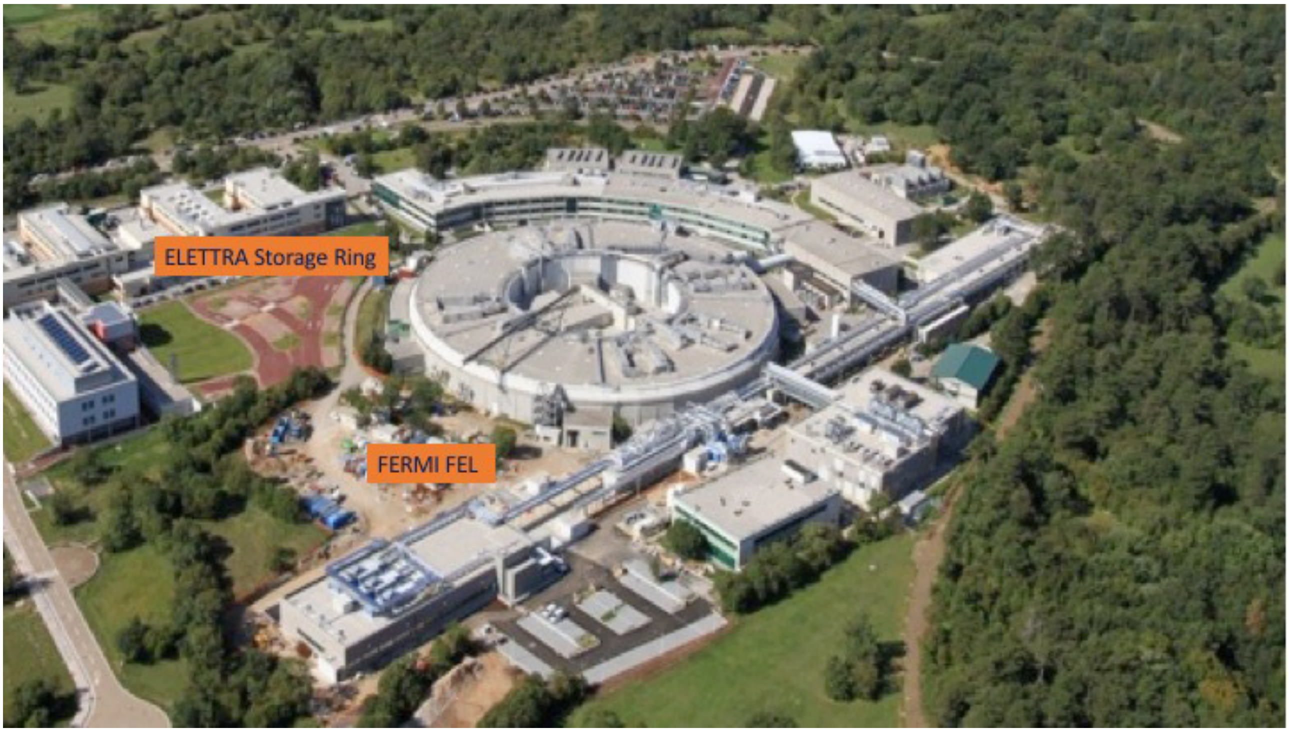

Figure 1: Elettra - Sincrotrone Trieste Lab: FERMI FEL and ELETTRA storage ring.

FERMI

The FERMI FEL project (the civil infrastructure was completed by 2010) required the excavation and construction of several new buildings to house the accelerator, experimental area and associated offices and laboratories. It also required the extension of the existing Elettra linac tunnel (no longer used since the installation of the new full energy injector booster) in both upstream and downstream directions and the excavation and construction of the FEL undulator and experimental hall. New conventional systems were provided as the upgrading of the existing ones.

The linac is situated below ground at a depth of ~5 m in a tunnel. The existing linac tunnel was extended backwards by an additional ~80 m and a surface area of ~400 m^2. The control room for the FEL (and later also used for Elettra) are situated at ground level approximately midway along the linac accelerator.

The Klystron gallery at ground level is housing the RF power sources and the dedicated ancillary equipment, located above the linac tunnel.

The FEL can operate at 10 or 50 Hz and the linac max. energy is 1.55 GeV (at 10 Hz). The electrical power requested for FERMI operation at 10 (50) Hz is about 1 (1.4) MW and 0.8 MW in shutdown

Trigeneration Plants

During the development of FERMI project, it was decided to construct two new (identical) Trigeneration plants (TGP-1, TGP-2) firstly, to satisfy the UPS (Uninterruptible Power Supply) requirement of both machines, secondly, for high efficiency production of electricity and cold/hot water. Figure 2 shows the location of the two plants. At the beginning, the first plant was constructed to serve FERMI FEL, the second one to Elettra Storage Ring, but in any case it was decided the installation of a complete hot-cold water/electrical grid system (called LINK) between these two plants in order to have the flexibility to use only one as UPS system and the other as simple generator, connected in parallel to the utility grid or (for example) to be switched off in case of maintenance.

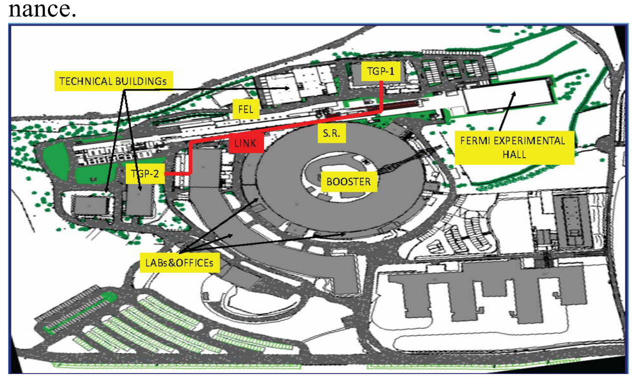

Figure 2: Elettra - Sincrotrone Trieste buildings.

Each Trigeneration plant is made up of 3 endothermic (natural) gas fuelled engines with covers for heat recovering, generating a total operating power of about 1.8 kWe, one combined absorber and heat pumps. The Trigeneration block diagram is shown in figure 3.

TGP-1,2 usually work at about 75% of nominal power (if working as UPS system), in order to have a redundancy in the case one motor has a fault. In this case, engines/generators continuously run to supply electrical power in parallel with the utility grid and in the case it is no longer available a "flywheel" switch system (produced by PILLER and having a capacity of about 1.0 MW) disconnects the microgrid (from the utility grid) allowing the connected lab's devices to operate. If the TGP is not used/connected as UPS system, it detects islanding and immediately stops producing power.

Each TGP system has a heating power of about 2.3 kWt and a cooling power of about 1.5 kWf. The total electrical energy requirement for the laboratory, per one year, (including the two accelerators) is about 50 GWh and about 40% coming from TGP-1 e 2. The heat energy required by the lab (about 6 GWh) is totally provided by TGP-1,2. The cooling energy provided by TGP-1,2 is about 10 GWh, not sufficient to cover the needs of the lab.

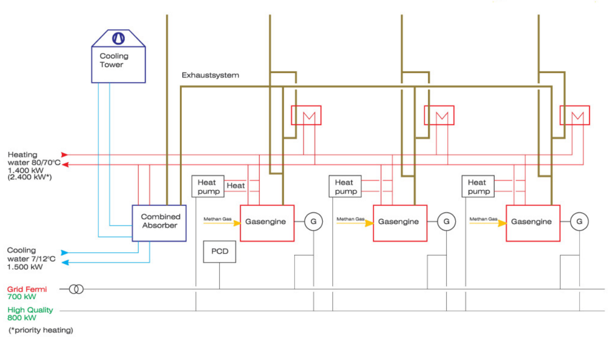

Figure 3: TGP scheme.

MECHANICAL - ELECTRICAL PLANTS

FERMI and Elettra cooling system is made up of a primary circuit (~15 °C) that cools a secondary demineralised water circuit (~27 °C). Primary circuit, using the domestic water, includes cooling tower (mainly used in summer) and chillers.

FERMI has a tertiary cooling circuit mainly dedicated to stabilize the temperature of RF systems, having very tight temperature tolerances (the temperature must be regulated within 0.1°C at different temperature working point). It consists of local pumps, heat exchanger, piping, regulation valves and dedicated equipment to control and monitor the system. Each linac accelerator section has a dedicated tertiary system devoted to maintain the temperature constant at selected value.

HVAC system is in use for both Elettra and FERMI. HVAC plants are positioned on the roof of the storage ring (Elettra) and close to the FERMI tunnel, in order to minimize the length and quantity of the ducts. In general, any plant has redundancy in the principal components in order to guarantee continuity of operation.

The specified room temperature stability for FERMI is typically ±1 °C, however in some rooms we have more stringent tolerances. For example in Undulator Hall the tolerance is ±0.5 °C and ±0.25 °C in the Seed and Photo-injector Laser Rooms. Also the humidity is kept under strict control. Generally the measured values are much better than specification, for example the measured temperature stability in FERMI Undulator Hall is ~ 0.3 °C (peak to peak). In Elettra storage ring, the temperature is normally kept constant within -0.6 °C (peak to peak). The temperature specification for the machine and service gallery was originally ± 0.5°C.

Elettra - Sincrotrone Trieste is connected to the utility grid by two 20 kV incoming lines. The total available power is 12 MW. Electric substations then transform the 20 kV lines to 400 V/230 V lines and are connected via a cabled network using underground or suspended conduits.

CONCLUSION

The electrical and cooling systems have demonstrated a good reliability for both machines. Elettra, in operation for users since 1994 for about 5000 hours per year, with an availability index (uptime) greater than 95%, has showed an average downtime of about 30 hours/year (2016) due to the cooling systems (and no downtime for the electrical system). FERMI, in operation for users since 2012, has shown an average availability in the range 80-90% and a total downtime, due to the cooling systems, of about 30 hours (2016) (and no downtime due to the electrical system). The faults are generally equally distributed among all the cooling systems components.

About the new storage ring that will replace the actual Elettra [2], in the same tunnel while respecting all photon source point positions (from Insertion Devices), an infrastructure study has been carrying out. The new machine has been designing also with the objective of increasing significantly the global energy efficiency: electricity is a relevant part of the running cost of an accelerator. It has been estimated that the new machine should have an energy consumption reduction of about 33%. The design of the new (or refurbished) plants must then take this into account as well as the demanding temperature stability, about one order of magnitude better than actual machine. A detailed study of the temperature stability and distribution for storage ring and service area will be carried out to meet the specified requirements.

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