INTERLOCK SYSTEM FOR MACHINE PROTECTION AT THOMX ACCELERATOR

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Abstract

ThomX is a Compton based photons source. It aims to produce a compact and directional X-rays source, with high performance, high brightness and adjustable energy [1]. The principal application fields are medical sciences, social technology and industry. An interlock system has been implemented for machine protection, especially to protect sensitive and essential equipment (magnets, vacuum system, etc.) during machine operation. It will allow taking appropriate actions to minimize recovery time in case of operation problem. ThomX interlock system is based on Programmable Logic Controller (PLC-Siemens S7-1500) distributed over the machine subsystems, it collects default signals from the different equipment of the machine, up to the central PLC which kills the beam, by stopping the RF or the injection, in case of problem (bad vacuum, magnets overheating, etc.). Actually, the interlock system is under implementation in parallel with the assembly of the machine. It will allow accelerator to work safely, and increase the availability of the machine.

INTRODUCTION

ThomX is a compact light source project where the Compton Effect is used to produce X-rays. A circular accelerator is combined to a high power laser, amplified in an optical cavity, to obtain collisions between an electron beam and the light pulses.

The collision between electrons and photons induces a diffusion of photons in the electrons direction with a high energy gain. Thus, from a few eV photons it is possible to obtain "hard» X-ray (a few tens of keV) using a 50 MeV accelerator. The machine presents the advantage of a compact dimensions (70 m2) and low costs.

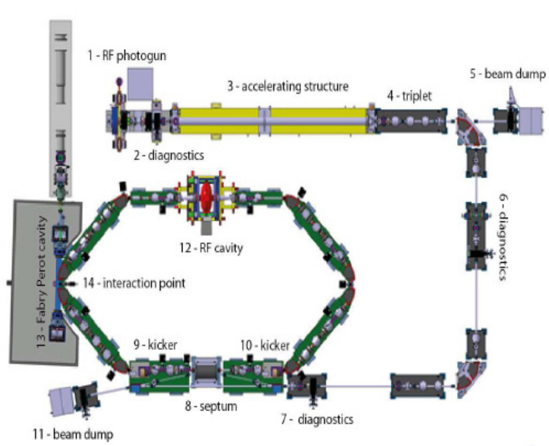

Figure 1: ThomX layout

Figure 1 shows the general layout of the machine. It is composed of four main systems: the injector, the storage ring, the laser and the Fabry-Pérot resonator.

The linac includes an electron RF photogun followed by an acceleration structure. The injection line consists of dipoles to steer the beam, quadruples and two diagnostic stations for energy spread measurements and beam characterization. The injection is performed by a septum and a fast kicker. [2].

The ring includes dipoles, quadruples, and sextuples for chromatic corrections. An RF cavity is used to bunch the electrons and to perform a longitudinal feedback.

The potential applications of this type of machine are numerous, including medical sciences, social technology and industry. Through collaboration between different French laboratories and industrials, it will be possible to share the technological excellence that will allow ThomX to be one of the most efficient machines in the world.

INTERLOCK SYSTEM DESCRIPTION

Because of the high beam power and energies in accelerator, the risk of beam induced damage is significant [3]. An interlock system is then used to protect the very sensitive and essential equipments (BPMs, vacuum chambers and valves, magnets) during machine operation. The ThomX interlock system is based on industrial programmable logic controller (PLC Siemens S7-1500 [4]). It collects default signals from the different equipment of the machine up to the central PLC which shut down the beam, by stopping the RF or the injection, when some parameters drifts outside specifications (bad vacuum, magnets overheating, etc.).

The interlock system consists of two levels. The first one is a local process, whose role is to monitor the variations of different parameters of the machine equipments, and generates a default signal in case of operation problem. The second level is the central PLC, which gathers and processes all the default signals from subsystems, and stops the RF power in a very short time.

To measure the performance of an interlock machine, we are based on two major parameters: reliability which measures the probability of fulfilling the major design function of the system, continuously and without interruptions, for a predefined period of time. The other parameter is the availability which defines the probability to find the machine fulfilling its major design function, when it is claimed to be in operation [5].

These two parameters describe the aptitude of the interlock system to meet the security requirements and to avoid failures.

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ARCHITECTURE OF THOMX INTERLOCK SYSTEM

The interlock system is based on PLC technology (Siemens S7-1500). Low level (process level) modules are distributed around accelerators subsystems (figure 2). They are connected together to the master controller (interlock level) that collects the defaults signal and stops the RF by a redundant wired signal. The PLC of the interlock level is connected via Ethernet to the control interface (Panorama [6]) for default monitoring and signals reset. The architecture of ThomX interlock system is shown in figure2.

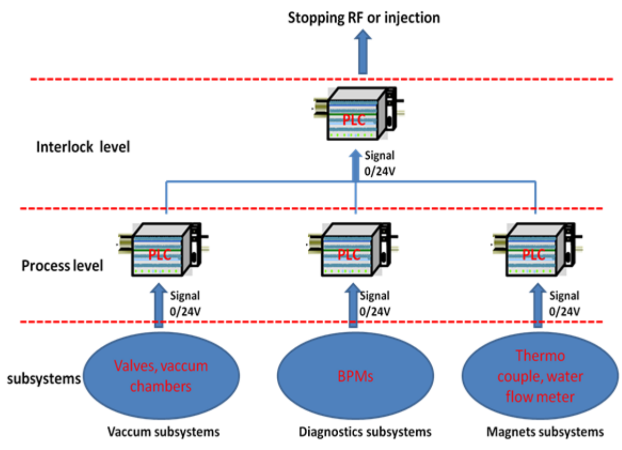

Figure 2: Interlock system architecture

The interlock system is designed basically to protect three sensitive area of the accelerator: magnets, BPMs and vacuum components.

Beam Position Interlock

A beam position monitor (BPM) allows detecting the beam position and assisting to maintain the beam path in beampipe axis. 17 BPM are distributed along the accelerator within 4 cells: storage ring cell 1 (6 BPMs), storage ring cell 2 (6 BPMs), Linac (1 BPM) and the transfer line (4 BPMs). All BPMs are driven by an electronic module (LIBERA [7]) which ensures signal acquisition and processing. Libera modules are connected to the process level PLC, it generate default signal when the parameters of the beam drift from specifications. The interlock signal is set within a millisecond whenever the electron beam position trespasses one of the predefined thresholds. This allows catching up the drift in short duration and avoiding damage to the machine.
The BPM interlock is an essential security component that protects with confidence the machine from orbits shifts.

Magnet Interlock

The magnet interlock system (figure3) is designed to protect magnets from overheating in case of failure of powering or cooling systems. It switches off the power supplies in a minimum time, and sends an error message to the control system to indicate the origin of failure. To ensure short time reaction, the magnet interlock system is a local process, and requires the intervention of a technician to rest the system in case of interlock outbreak.

The magnet security concern 12 dipoles distributed along three subsystems of the accelerator: 8 dipoles in the ring, 4 dipoles in the transfer line and 2 dipoles in the extraction line. To protect the dipoles from overheating, a set of thermocouples and water flow meters are installed in each dipole. when the threshold of the temperature or flow level is reached.

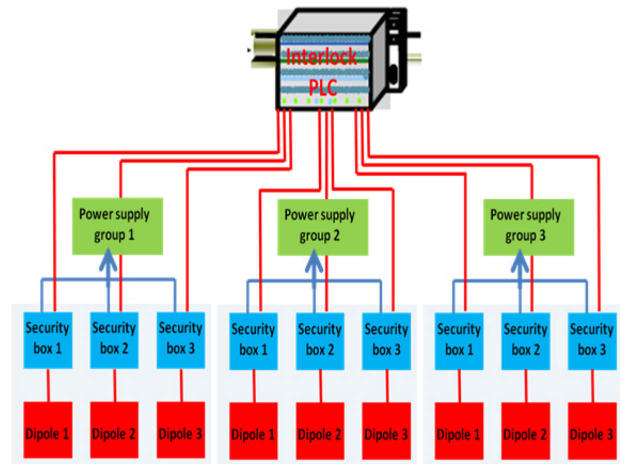

Figure 3: Architecture of magnet interlock

An electronic security box is connected to each dipole; it collects the information of water temperature and outflow and generates a default signal The security boxes of each group are linked in series (figure 3). In case of problem of temperature or water flow on a magnet, one default signal is sent to stop automatically the power supply of the corresponding group with a maximum delay less than 1 second. However all the security boxes are linked to the interlock PLC to indicate the defective magnet and to stop beam operation if needed.

Vacuum Interlock

The main objective of the vacuum interlock is to protect the machine equipments in case of bad or very bad vacuum. This process stops the beam when the vacuum threshold is reached, and allows also checking the positions of valves before authorizing the beam emission.
The accelerator beampipe is divided into several volumes bounded by automatic valves. Multiple ion pumps are installed on each volume. The pumps are connected in series and generate one interlock signal per volume when thresholds are reached for the corresponding volume. The vacuum thresholds are defined as follows: a normal vacuum/bad vacuum threshold around 10^{-7} mbar, and a very bad vacuum threshold corresponding to the disjunction of the ion pump power supply.

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The vacuum security process is defined as follow:

- The bad vacuum (BV) threshold stops the beam emission; the operation of the modulator is locked to the threshold (BV) of the ion pump.
- The very bad vacuum (VBV) threshold of all ion pumps (between two valves) upstream and downstream of an automatic valve controls the closing of the valves. The valves can then only be opened after return of good vacuum of the relevant volume, and an open action from the control-command system.

The vacuum interlock system controls 28 default signals from the ion pumps, corresponding to two vacuum thresholds. It controls also the position of 11 automatic valves.

CONCLUSION

In this paper, we presented the operation principle and the architecture of ThomX interlock system, and its importance to avoid equipment damage. The system is actually under implementation in parallel with the assembly of ThomX machine. The future work includes the integration of the interlock system in the supervision interface of ThomX in order to unify the control tool and facilitate the default management. The test phase will start with the commissioning of ThomX, and will include essentially the verification of the response time and the reliability.

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